U.S. CONGRESS

JOINT COMMITTEE ON ATOMIC ENERGY

Hearings 1960
Volume 1

HD
9698
.U5
A35
1960a

CONTENTS

National food irradiation research program...

Part 1, Jan. 14-15, 1960
Part 2, Mar. 31, 1960

Development, growth, and state of the atomic energy industry... Feb. 16 - 25, 1960.

NATIONAL FOOD IRRADIATION RESEARCH PROGRAM

HEARINGS

BEFORE THE

JOINT COMMITTEE ON ATOMIC ENERGY

CONGRESS OF THE UNITED STATES

EIGHTY-SIXTH CONGRESS

SECOND SESSION

ON

NATIONAL FOOD IRRADIATION RESEARCH PROGRAM

JANUARY 14 AND 15, 1960

PART 1

Printed for the use of the Joint Committee on Atomic Energy

UNITED STATES
GOVERNMENT PRINTING OFFICE
52249 WASHINGTON : 1960

JOINT COMMITTEE ON ATOMIC ENERGY

CLINTON P. ANDERSON, New Mexico, *Chairman*
CARL T. DURHAM, North Carolina, *Vice Chairman*

RICHARD B. RUSSELL, Georgia
JOHN O. PASTORE, Rhode Island
ALBERT GORE, Tennessee
HENRY M. JACKSON, Washington
BOURKE B. HICKENLOOPER, Iowa
HENRY DWORSHAK, Idaho
GEORGE D. AIKEN, Vermont
WALLACE F. BENNETT, Utah

CHET HOLIFIELD, California
MELVIN PRICE, Illinois
WAYNE N. ASPINALL, Colorado
ALBERT THOMAS, Texas
JAMES E. VAN ZANDT, Pennsylvania
CRAIG HOSMER, California
WILLIAM H. BATES, Massachusetts
JACK WESTLAND, Washington

JAMES T. RAMEY, *Executive Director*
JOHN T. CONWAY, *Assistant Director*
EDWARD J. BAUSER, *Technical Adviser*

DEPOSITED BY THE
UNITED STATES OF AMERICA

61
3205
E66
12 vols.

CONTENTS

HEARING DATES

Page

Thursday, January 14, 1960 ---- 1
Friday, January 15, 1960 ---- 93

ATOMIC ENERGY COMMISSION WITNESSES

Floberg, John F., Commissioner ---- 72
Hollingsworth, Robert E., Deputy General Manager ---- 72
Shilling, Dr. Charles W., Deputy Director, Division of Biology and Medicine ---- 72
Aebersold, Dr. Paul C., Director, Office of Isotopes Development ---- 72

DEPARTMENT OF THE ARMY WITNESSES

Beale, Dr. Frank D., Jr., R. & E. Division, Office of the Quartermaster General ---- 2
Ely, Brig. Gen. W. J., Director of Army Research, Office of Chief of Research and Development ---- 2
MacLaughlin, Maj. Gen. V. J., Office of the Quartermaster General ---- 2
Morse, Richard S., Director of Research and Development ---- 2
Nungester, Dr. Walter J., Army Scientific Advisory Panel member and director of bacteriology, University of Michigan Medical School ---- 2
Oliver, Col. R. H., Deputy Chief, Life Sciences Division, Office of Chief of Research and Development ---- 2
Schwab, Dr. John L., special assistant to the Director of Research and Development ---- 2
Siu, Dr. R. G. H., Technical Director, R. & E. Division, Office of the Quartermaster General ---- 2
Youmans, Dr. J. B., Technical Director, Medical Research and Development Command, Office of the Surgeon General ---- 2

STATEMENTS OF OTHER WITNESSES

Kraybill, Dr. Herman F., Curtiss-Wright Corp. Nuclear Radiation Department ---- 94
McFall, Hon. John J., a Representative in Congress from the State of California ---- 69
Urbain, Walter M., director of engineering research, Swift & Co ---- 117

STATEMENTS AND ADDITIONAL MATERIAL SUBMITTED FOR THE RECORD (BY ORGANIZATION OR AFFILIATION)

Army Research and Development, statement of Richard S. Morse, Director ---- 66
Consumers Public Power District, by Emerson Jones, special assistant to the general manager, concerning a continuing aggressive program of development of irradiation and the possibilities of irradiation at Hallam plant ---- 127
Department of Health, Education, and Welfare to JCAE regarding responsibilities in the matter of irradiated food and participation in the Interdepartmental Committee on Radiation Preservation of Food ---- 125
Department of the Army, press release of October 22, 1959, concerning deferment of construction of Army Ionizing Radiation Center at Stockton, Calif., pending further study ---- 25
Nucleonics magazine, December 1959 issue, editorial entitled "Is This Bold Leadership?" ---- 90
Nucleonics magazine, article from January 1960 issue, by Herman F. Kraybill, entitled "Are Irradiated Foods Harmful?" ---- 95

CORRESPONDENCE INSERTED IN THE RECORD

Page

Loper, Herbert B., Assistant to the Secretary of Defense (Atomic Energy), to Hon. Melvin Price, dated October 16, 1959, outlining reasons for suspending construction of the Army Ionizing Radiation Center at Stockton, Calif 22

Luedecke, A. R., General Manager, AEC, to Dr. Richard S. Morse, Director of Research and Development, Army, dated August 31, 1959, concerning material for review on induction of activity in irradiated foods 54

Luedecke, A. R., General Manager, AEC, to James T. Ramey, Executive Director, JCAE, dated November 19, 1959, submitting comments on deferred irradiation project at Stockton, Calif 48

Morse, Richard S., Director of Research and Development, Army, to Gen. A. R. Luedecke, General Manager, AEC, dated August 23, 1959, re radiological safety for consumption of irradiated foods 52

Morse, Richard S., Director of Research and Development, Army, to James T. Ramey, Executive Director, JCAE, dated March 16, 1960, enclosing revised version of Army Food Irradiation Center 115

Ramey, James T., Executive Director, JCAE, to Gen. A. R. Luedecke, General Manager, AEC, dated October 27, 1959, requesting comment on deferral of food irradiation project at Stockton, Calif 48

Ramey, James T., Executive Director, JCAE, to Gen. A. R. Luedecke, General Manager, AEC, dated October 28, 1959, asking information on disposition of funds authorized for AEC portion of deferred irradiation project at Stockton, Calif 48

Ramey, James T., Executive Director, JCAE, to Richard S. Morse, Director of Research and Development, Army, dated February 26, 1960, concerning modified version of Army Food Irradiation Center 115

Roe, Robert S., Director, Bureau of Biological and Physical Sciences, Food and Drug Administration, HEW, to Hon. Clinton P. Anderson, dated January 20, 1960, on the use of antibiotics for the preservation of food 110

APPENDIXES

Appendix 1:

Ad hoc panel report to the Interdepartmental Committee on Radiation Preservation of Foods on a national civilian radiation processed foods program 133

Food Preservation by Ionizing Energy, Army revised program dated December 1959 147

Food Preservation by Ionizing Energy, Army revised program dated March 11, 1960 243

Appendix 2:

Material indicating that irradiated foods may have toxic and pathological effects in animals when ingested over a long period of time 251

Appendix 3:

Logistic and Economic Feasibility Study on Radiation Sterilization of Foods, R. J. Beeley, North American Aviation, Inc., official investigator 473

Appendix 4:

Evaluation of Size of USAIRC and Logistics of Irradiated Meat, report to Quartermaster Radiation Planning Agency, Quartermaster R. & D. Command 571

Appendix 5:

An Evaluation of the Technical, Economic, and Practical Feasibility of Radiation Preservation of Fish by B. E. Proctor, S. A. Goldblith, J. T. R. Nickerson, and D. F. Farkas, Department of Food Technology, Massachusetts Institute of Technology 629

Appendix 6:

Growth, Reproduction, Survival, and Histopathology of Rats Fed Beef Irradiated With Electrons, by C. E. Poling, W. D. Warner, F. R. Humburg, E. F. Reber, W. M. Urbain, and E. E. Rice, Research Laboratories, Swift & Co 646

NATIONAL FOOD IRRADIATION RESEARCH PROGRAM

THURSDAY, JANUARY 14, 1960

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C.

The Joint Committee met, pursuant to notice, at 10 a.m., in room P-63, the Capitol, Senator Clinton P. Anderson (chairman) presiding.

Present: Senator Anderson, Hickenlooper, Dworshak, Aiken; Representatives Durham, Holifield, Price, Aspinall, Van Zandt, Bates, and Westland.

Also present: James T. Ramey, executive director; John T. Conway, assistant director; Richard T. Lunger, staff consultant; and Edward J. Bauser, technical adviser, Joint Committee on Atomic Energy.

Chairman ANDERSON. The committee will be in order.

This is an open public hearing of the Joint Committee on Atomic Energy to consider the current status of the food irradiation research program.

The Joint Committee has been interested in the possibility of sterilization of food by radiation for many years. We remember the agreement in 1954 between the Atomic Energy Commission and the Department of Defense when it was decided that the Army would undertake responsibility for support of food-preservation work. In hearings before the Subcommittee on Research and Development of the Joint Committee on Atomic Energy, in 1955 and 1956, we remember the marvelous reports and glowing predictions that were made by representatives of the Army based upon the results of their work.

In hearings before the Subcommittee on Research and Development in June 1956 we were told that construction of the Army Ionizing Radiation Center would begin in 1957 and be in operation by 1958. These were given to us as "definite practical target objectives." In October 1959 the Army announced that it was suspending plans for construction of the Ionizing Radiation Center, stating that "certain physiological problems had not yet yielded to solution in the laboratory," and indicating that there was some question as to the economic justification for the project. In addition, the Army at the time it suspended this project also made certain statements raising a question to the effect that its decision was prompted in part by reported biological changes in some experimental animals.

I want to admit that I thought it was a wise precaution for the Army to suspend their plans, and say so publicly, at that time—there were some problems.

We want to know what actually prompted the Army's decision and what scientific, technical or economic basis arose to justify the Army's

change of plans. We are particularly interested in ascertaining what effect the sudden cancellation of this planned project will have on the overall national food irradiation research program. Representatives of the Department of the Army, charged with responsibility for this program, have been requested to appear here this morning to review the history and the background of the program and to discuss its current status.

Mr. Richard S. Morse, Director of Research and Development, and Brig. Gen. William J. Ely, Director of Research, Office of Chief of Research and Development, Department of the Army, are with us this morning, I understand, with their associates, to discuss this with the committee.

If the representatives of the Army are ready, we may proceed.

STATEMENT OF RICHARD S. MORSE, DIRECTOR OF RESEARCH AND DEVELOPMENT, DEPARTMENT OF THE ARMY, ACCOMPANIED BY DR. JOHN L. SCHWAB, SPECIAL ASSISTANT TO THE DIRECTOR OF RESEARCH AND DEVELOPMENT; MAJ. GEN. V. J. MacLAUGHLIN, OFFICE OF THE QUARTERMASTER GENERAL; BRIG. GEN. W. J. ELY, DIRECTOR OF ARMY RESEARCH, OFFICE OF CHIEF OF RESEARCH AND DEVELOPMENT; COL. R. H. OLIVER, DEPUTY CHIEF, LIFE SCIENCES DIVISION, OFFICE OF CHIEF OF RESEARCH AND DEVELOPMENT; DR. R. G. H. SIU, TECHNICAL DIRECTOR, R. & E. DIVISION, OFFICE OF THE QUARTERMASTER GENERAL; DR. J. B. YOUMANS, TECHNICAL DIRECTOR, MEDICAL RESEARCH AND DEVELOPMENT COMMAND, OFFICE OF THE SURGEON GENERAL; FRANK D. BEALE, JR., R. & E. DIVISION, OFFICE OF THE QUARTERMASTER GENERAL; DR. WALTER J. NUNGESTER, ARMY SCIENTIFIC ADVISORY PANEL MEMBER AND DIRECTOR OF BACTERIOLOGY, UNIVERSITY OF MICHIGAN MEDICAL SCHOOL, ANN ARBOR, MICH.

(Mr. Morse's written statement appears on p. 66.)

Mr. MORSE. Mr. Chairman, I am Richard S. Morse, Director of Army Research and Development, and have been designated to represent the Army today. I have supporting witnesses whom I would like to introduce to you.

Dr. John L. Schwab, special assistant to the Director of Research and Development.

Maj. Gen. V. J. MacLaughlin, Office of the Quartermaster General.

Brig. Gen. W. J. Ely, Director of Army Research, Office, Chief of Research and Development.

Col. R. H. Oliver, Deputy Chief, Life Sciences Division, Office, Chief of Research and Development.

Dr. R. G. H. Siu, Technical Director, R. & E. Division, Office of the Quartermaster General.

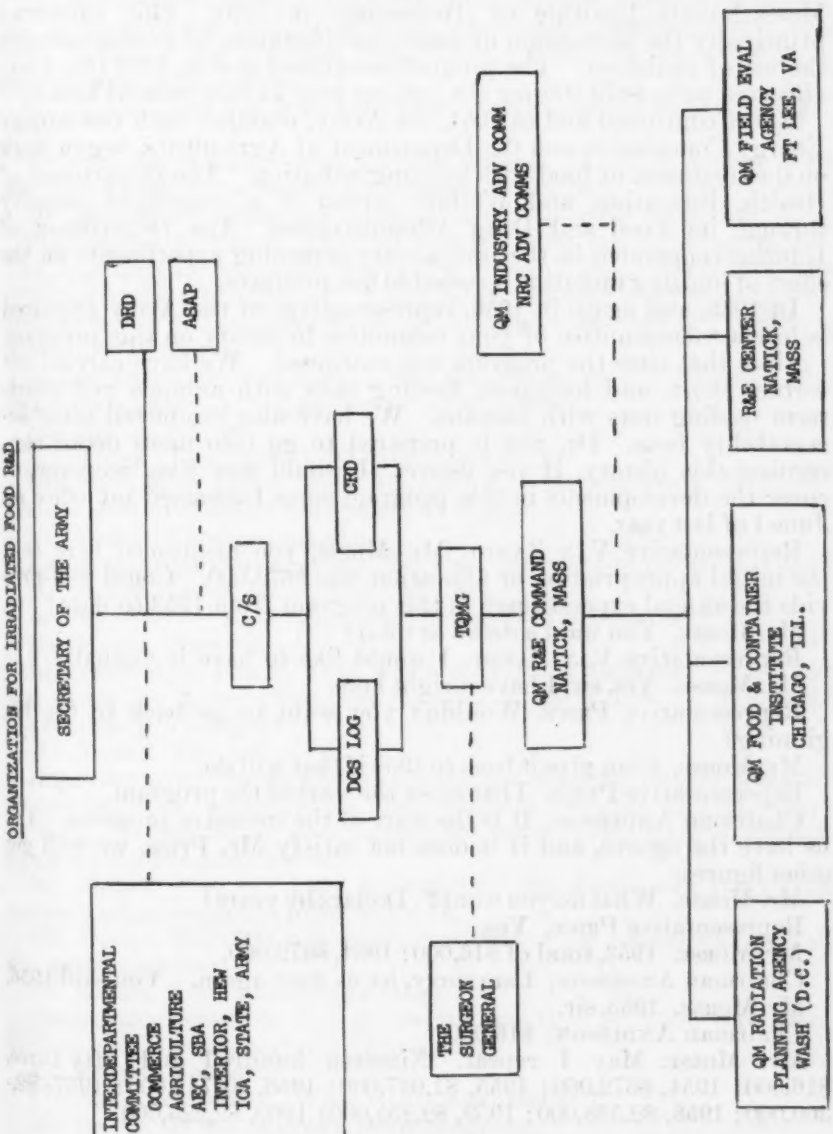
Dr. J. B. Youmans, Technical Director, Medical Research and Development Command, Office of the Surgeon General.

Dr. Frank D. Beale, Jr., R. & E. Division, Office of the Quartermaster General.

Dr. Walter J. Nungester, Army Scientific Advisory Panel member and director of bacteriology, University of Michigan Medical School, Ann Arbor, Mich.

My plan for the presentation is to cover very briefly the history of the program and then to answer to the best of my ability the questions which you have indicated to be of a particular interest—specifically my reasoning for the actions taken since assuming my position of Director of Research and Development on June 1, 1959.

Here is a chart which shows the Army's organization for research and development of irradiated foods.



I believe organization was a subject to which you had directed your interest. In this chart, I might say, of course, we have only covered the activities under the jurisdiction of the Secretary of the Army. We have, of course, also had certain inputs and correlations with the Department of Defense, Dr. York's office, the Atomic Energy Commission, and other agencies of the U.S. Government. But this, I think, will indicate to you the so-called lines of command which are employed within the Department of Army for accomplishing this research and development activity.

As you will recall the Army effort was initiated in the early 1950's. One of the earliest projects was a quartermaster research contract with Massachusetts Institute of Technology in 1951. This concerned principally the prevention of insect manifestation of cereals through the use of radiation. The program continued and in 1953 the Army allocated some $672,000 for the coming year in this general area.

Effort continued and in 1954, the Army, together with the Atomic Energy Commission and the Department of Agriculture, began work on the treatment of food with ionizing radiation. The Department of Health, Education, and Welfare served in a consultant capacity through its Food and Drug Administration. The Department of Interior cooperated in the preliminary screening experiments on the effect of ionizing radiation on selected fish products.

In 1955, and again in 1956, representatives of the Army appeared before a subcommittee of your committee to testify on this program.

Since that time the program has continued. We have carried out certain short- and long-term feeding tests with animals and short-term feeding tests with humans. We have also conducted some acceptability tests. Dr. Siu is prepared to go into more detail concerning this history, if you desire. I would now like, however, to cover the developments in this program since I assumed my office on June 1 of last year.

Representative VAN ZANDT. Mr. Morse, you mentioned here that the initial appropriation or allocation was $672,000. Could you provide the annual expenditures in this program from 1953 to date?

Mr. MORSE. You want a detail or total?

Representative VAN ZANDT. I would like to have it annually.

Mr. MORSE. Yes, sir, I have it right here.

Representative PRICE. Wouldn't you want to go back to the beginning?

Mr. MORSE. I can give it back to 1953 if that will do.

Representative PRICE. That is not the start of the program.

Chairman ANDERSON. It is the start of the intensive program. Let us have the figures, and if it does not satisfy Mr. Price, we will get other figures.

Mr. MORSE. What do you want? Dollars by years?

Representative PRICE. Yes.

Mr. MORSE. 1953, total of $16,000; 1954, $672,000.

Chairman ANDERSON. I am sorry, let us start again. You said 1956.

Mr. MORSE. 1953, sir.

Chairman ANDERSON. $16,000.

Mr. MORSE. May I repeat. Nineteen hundred and fifty-three, $16,000; 1954, $672,000; 1955, $1,047,000; 1956, $1,742,000; 1957, $2,300,000; 1958, $2,538,000; 1959, $2,255,000; 1960, $2,225,000.

Chairman ANDERSON. Is that fiscal 1960?

Mr. MORSE. Yes, sir. These are all fiscal years, sir. Does that answer your question?

Representative PRICE. Mr. Van Zandt asked the question. It does not completely answer what I would like to know. Is that operating and construction?

Mr. MORSE. This is total research and development funds within the Army. No construction.

Representative VAN ZANDT. Have you a total on it?

Mr. MORSE. It is approximately $13 million.

Representative PRICE. I don't think the picture is complete unless you go back to the beginning to see what your program was. The Army initiated the program about 1950. What was happening in those days or what was spent?

Mr. MORSE. Are you directing your question to the period 1950 to 1953?

Representative PRICE. You are the witness. I am directing it to you, but if you can't answer, maybe someone else can.

Mr. MORSE. I can answer if you will tell me what you want.

Representative PRICE. The full amount from the time you began. You have in your statement "as you will recall the Army effort was initiated in the early 1950's." I dn't think you get a complete financal picture unless you give the whole financial picture from the time you started the program.

Mr. MORSE. I believe this is the total funding. I will ask Mr. Beale, do we have any expenditures before 1953?

Mr. BEALE. No, sir.

Mr. MORSE. That is the total expenditures.

Representative PRICE. Then they did not initiate much of a program in 1950 if they did not spend any money.

Mr. MORSE. That is right, sir.

Representative PRICE. When did they initiate the program, then?

Mr. MORSE. In 1953, they spent $16,000.

Representative PRICE. That was the start of the program?

Mr. MORSE. Yes, sir.

Representative PRICE. Then what does your statement mean, "As you recall the Army effort was initiated in early 1950"? Was 1953 the earliest you started?

Mr. MORSE. Yes, sir.

Representative PRICE. One of the earliest projects was the quartermaster research contract with Massachusetts Institute of Technology in 1951. You certainly must have spent some money on that project. I just want a complete answer.

Mr. MORSE. Yes, sir; I see your point. Mr. Beale, can you advise me as to what was spent prior to 1953?

Mr. BEALE. $672,000 was spent, but that is not considered part of the present project.

Mr. MORSE. I don't understand that.

Chairman ANDERSON. Let us understand that $672,000 was spent and not considered a part of this program?

Mr. BEALE. Yes, sir.

Chairman ANDERSON. What was it considered?

Mr. BEALE. It was part of a prior program.

Mr. MORSE. I think we want the total funding of the irradiation program of the Army. I understand these figures from 1953 constitute the total funding. Can you give us the figures prior to 1953?

Mr. BEALE. $672,000.

Representative PRICE. I don't want to do this for the sake of argument. I want to have a history of the beginning of the program and what you did on it from the start and how that progressed or failed to progress.

Mr. MORSE. I think your point is very well taken. Is that the total figure, then? There was $670,000 prior to 1953?

Mr. BEALE. That is right.

Representative PRICE. Why don't you get for the purpose of the record the date the program started, what you did, what the MIT contract amounted to, what they did or how much it cost, and so forth. Furnish that for the record.

Mr. MORSE. I might say, sir, the figures I have here I received on January 11, from the Quartermaster Corps and they are started in 1953. I gather, as you have indicated, there were expenditures prior to that date.

Representative PRICE. You indicated it in your statement.

Mr. MORSE. I understand that, sir. Mr. Beale is here and he should have those figures and I suggest that he give them to us accurately at the present time. Will you do that, Mr. Beale?

Mr. BEALE. I will furnish it for the record.

Representative PRICE. I am not doing it for the sake of argument. I would like to have it in the record.

(The breakdown of funds follows:)

PRELIMINARY INVESTIGATIONS PRIOR TO INCEPTION OF FORMAL ACCELERATED PROGRAM STARTED IN 1953

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

W-11-009-QM-19888:
Period: June 17, 1952, to December 31, 1953.
Amount: $19,891.
Subject: Research on "Application of Electronic Treatment to Destruction of Insects in Packaged Military Rations and Packaged Materials."

W-11-009-QM-18846:
Period: June 1 to November 30, 1952.
Amount: $7,820.
Subject: "Experiments and Tests in the Field on Cathode Ray Sterilization of Perishable Foods (Meat Ration, Vegetable and Fruit Juice)."

FUNDING DATA

Radiation preservation of food (formal accelerated program)

Fiscal year	R. & D. Army funds	O. & M. Army funds	Total
1953	$16,000		$16,000
1954	672,000		672,000
1955	1,047,000		1,047,000
1956	1,588,000	$154,000	1,742,000
1957	1,094,000	1,206,000	2,300,000
1958	1,180,000	1,358,000	2,538,000
1959	1,039,000	1,216,000	2,255,000
1960	1,175,000	[1] 450,000 [2] 600,000	[3] 2,225,000
1961 (President's budget)	500,000		500,000
1961 (objectives budget)	1,265,000		1,265,000

[1] Programed.
[2] Unfinanced.
[3] Includes the $600,000 unfinanced O. & M.

NOTE 1.—Approximately ⅔ of the R. & D. funds are spent on outside contract and the balance spent in-house.
NOTE 2.—All of the O. & M. funds are spent on outside contract. Included in these funds are radiation services, the Surgeon General's wholesomeness studies, feeding tests that were conducted at Fort Lee.

DOD emergency funds

Fiscal year	Received	Obligated
1958	$2,500,000	
1959		$303,200
1960		[1] 22,700

[1] Through August 1959. Additional funds are being obligated to complete blueprints (approximately $150,000). If existing contract with Curtiss-Wright is then canceled, additional funds must be obligated for contract termination. This entire fund was transferred to the AEC, to design and construct a Cobalt-60 source.

U.S. ARMY IONIZING RADIATION CENTER

Army funds (industrial mobilization)

Fiscal year	Received	Obligated
1956	$500,000	$78,000
1957	2,830,000	705,000
1958		167,000
1959		287,000
1960:		
Programed		75,000
Obligated through November 59 [1]		42,000

[1] Additional industrial mobilization funds are required for personnel and operation of the Radiation Planning Agency, until phased out or included in another program.

NOTE.—The industrial mobilization funds listed above include funds for the nonnuclear portion of the pilot plant and for operation of the Radiation Planning Agency. The following is a breakdown of total funds programed for the nonnuclear portion of the pilot line, taken from "Project request for provision of production facilities funds," dated February 25, 1957:

Fiscal year 1956: Preliminary design	$200,000
Fiscal year 1957: Design and construction of linear accelerator	650,000
Fiscal year 1957: Pilot plant for irradiated foods	2,580,000
Fiscal year 1958: Pilot plant for irradiated foods	1,420,000
Total	4,850,000

Representative VAN ZANDT. Isn't it true that prior to 1953, you had a research project to explore the field and to establish any possibilities? Therefore, the Army has been involved in two programs; first to explore the field of irradiating food, and in 1953 you actually launched a program. The effort has been accelerated year after year until the present time.

Mr. MORSE. I think that is essentially correct, although that I don't believe there was a sharp demarcation at the point of 1953. It was exploratory during that entire period, but as the basic research became more definitive, we began thinking in the terms of this food irradiation center. Perhaps that is what you are saying.

Chairman ANDERSON. But the figure of $16,000 is not directly comparable to the figure of $672,000 because you were spending money in substantial amounts on other programs simultaneously. Would that be correct or not?

Mr. MORSE. I will have to refer to General MacLaughlin.

General MACLAUGHLIN. The dollars, Mr. Chairman, that are mentioned here relate specifically to the effort on irradiated foods in the overall food research and development program.

Chairman ANDERSON. What are the $672,000 related to that were spent prior to that. Did that not relate to irradiated foods?

General MACLAUGHLIN. That is the point I cannot answer at the moment, Mr. Chairman. We will get that specifically for the record.

Chairman ANDERSON. He [Dr. Siu] seems to be able to answer. Let him answer.

Mr. MORSE. Dr. Siu, can you answer that question?

Dr. SIU. Mr. Chairman, I would like to help clarify it. I doubt that we have given you the right impression on that $600,000 sum before 1953. I suspect that is the total amount spent on certain phases of food research, under which someone made some analysis, literature survey, and the like on food irradiation. Beginning in 1953, we began to churn the water a little bit with $16,000. Then at the end of 1953, or thereabouts, the Army decided to move ahead. I believe that is the correct picture, but I would like to request permission to clarify it, saying tentatively we might have given you a wrong figure.

Chairman ANDERSON. You may file a subsequent statement because that checks with my own understanding of what you did.

Dr. SIU. Yes, sir.

Chairman ANDERSON. You had a food research program that did not necessarily relate to the irradiation of food until you got underway in 1953. You give us any breakdown you can of this earlier amount of money, and why it is not regarded as primarily connected with this program.

Dr. SIU. Yes, sir.

Chairman ANDERSON. Thank you. I am sorry to take so much time on this, but we like to clarify as we go along.

Mr. MORSE. The Army Food Irradiation Center was to have been constructed at Stockton, Calif., at an estimated cost of $7.5 million. The proposed plant was to have been of sufficient size to conduct both pilot plant and limited production scale studies on a wide variety of foods utilizing two different ionizing sources, each capable of producing completely sterilized products.

Representative VAN ZANDT. What is the status of this $7.5 million project? How much money have we spent to date?

Mr. MORSE. Mr. Beale, would you answer that question, please?

Mr. BEALE. Would you repeat the question, sir?

Chairman ANDERSON. How much of this $7.5 million was spent, how much was not spent, what are you doing with the rest of the funds? Are they lying in trust somewhere?

Mr. BEALE. We have spent $1,654,000, sir.

Chairman ANDERSON. Has a building been built?

Mr. BEALE. No, sir.

Chairman ANDERSON. Has it been started?

Mr. BEALE. No, sir.

Mr. MORSE. Design and engineering studies have been completed.

Chairman ANDERSON. Is this for architect's plan and so forth?

Mr. BEALE. Yes, sir.

Mr. MORSE. I might add this is also for specialized equipment such as the accelerator and the high cobalt 60 source.

Chairman ANDERSON. This is for a building that is not being built.

Mr. MORSE. That is right.

Chairman ANDERSON. They are going to be put in storage until you actually need them?

Mr. MORSE. I don't know.

Chairman ANDERSON. What do you think you will do with them?

Mr. MORSE. We are currently waiting for a revised research program from the Quartermaster Corps which was requested.

Chairman ANDERSON. Can I say it this way: You had to do some advance purchasing in order to have the equipment available by the time the building was finished.

Mr. MORSE. It is more than that, Mr. Chairman. It was not a matter of purchasing in the sense of stock items. Both of the radiation sources which were to be required for this center required development work in themselves. There was a high voltage electron source and also a cobalt 60 source which is being made for the Army with Army funds which have been transferred to the Atomic Energy Commission. Both of these sources in themselves were research and development programs. A considerably longer leadtime was required than to just build a building of bricks and mortar. So that number which was given in our present release includes the preliminary design, test borings, the type of thing you do prior to construction, and the construction of two sources which were somewhat experimental, and still are. Neither of them has been completed.

Representative VAN ZANDT. Have you reached the hardware stage in any of your items?

Mr. MORSE. Not in the sense of the equipment having been completed. The major expenditures are only on these two sources. The other hardware items in the plant were standard types of equipment, food handling, and so on, such as you can buy off the shelf.

Representative PRICE. May I ask a question on that $1,600,000? Would that be part of the estimated cost of $7.5 million?

Mr. MORSE. Yes, sir. That is the total composite figure—design, construction, and installation of equipment.

Representative VAN ZANDT. In the event that the cancellation order sticks, you will have to negotiate with the contractors involved for a settlement. Wouldn't the $1,654,000 be increased, then?

Mr. MORSE. I would defer to General MacLaughlin on that, but my impression is initially no. The work has been stopped. It was stopped as of the time the decision was made to indefinitely suspend the plant. At the moment the so-called linear accelerator is being stored at the contractor's expense. These were cost-plus contracts in both instances. Is that correct, General?

General MACLAUGHLIN. That is right.

Mr. MORSE. I would not say there will be a tremendous amount of expense incurred in termination.

Chairman ANDERSON. Was the contract let for the building?

General MACLAUGHLIN. There was no contract let for the building, Mr. Chairman. The so-called part of this project that can be related to bricks and mortar was just the moneys that were spent to complete the architectural drawings and the detailed plans. We reached that point of time when the decision was made by the Department of the Army to take another look at this program.

Chairman ANDERSON. Have the architects been fully paid for their work done thus far?

General MACLAUGHLIN. They have been fully paid for that part of the work.

Chairman ANDERSON. Is there a reactor coming along in this connection? Is it ordered from somebody?

Mr. MORSE. There is no reactor. One of the original concepts in this long program involved the use of a reactor in which the AEC was involved. The decision was reversed, I believe, about the time that Mr. Foote was in DOD. The current plan, or the plan for the past several years has been to use a linear accelerator and cobalt 60 as two sources, and not to involve a reactor. We are using reactors, as you probably know, at the present time, as well as spent fuel rod elements and this type of thing. This plant will not employ a reactor.

Representative VAN ZANDT. Have the contracts been let for the accelerator and the use of cobalt 60?

Mr. MORSE. Yes, sir.

Representative VAN ZANDT. They have been suspended?

Mr. MORSE. Yes, sir.

Representative VAN ZANDT. Will you negotiate a settlement with the contractor or has the settlement been agreed to?

General MACLAUGHLIN. We have not effected any settlement at this time, sir. In our revised program we do not yet know to what extent we will use the cobalt 60 source or the linear accelerator. So we are holding that until such time as we get our revised program approved.

Representative VAN ZANDT. Then it is proper to say this figure of $1.6 million which has been expended to date on the project could be a little larger in years ahead in the event that you found no use for the accelerator or the cobalt 60 device?

General MACLAUGHLIN. In the event we have found no use for the cobalt 60 or the linear accelerator, there would be some termination costs; yes, sir.

Representative PRICE. The main reason for the building of the facility for $7.5 million was to prove or disprove the feasibility of the program. How has that changed? Don't you still need the facility to prove or disprove the feasibility of the program?

Mr. MORSE. I would like to answer that in this manner: This has been a long-term and expensive research and development activity as is perfectly obvious from the numbers I have quoted. The Army in very good faith felt that they might be able to telescope some time by combining the prototype testing of the two ionizing sources and obtain preproduction experience to demonstrate commercial feasibility of a process. At the time that this decision was made, it did appear that this might be a means whereby we might buy ourselves a couple of years' time in introducing irradiated meats into the Army food supply in particular. This decision in retrospect does not appear in my view to be a good one. This does not mean, however—and we have so recommended to the Quartermaster Corps—that all research should be stopped. This is a type of program, where perhaps we were a little hasty in proceeding with a relatively large and expensive integrated facility capable of supplying foods to large numbers of humans for test purposes. I think in a sense we have to go back to the bench and do some research, and get the fundamental information which we require prior to getting into a program of that magnitude.

The time to stop a research and development program is at the earliest possible moment you can, consistent with the urgency of the requirement. This seems to fit in that category. We have no urgent requirement for irradiated food in the Army as compared with the many other needs of our R. & D. activity.

Representative PRICE. What was the original intent of the Army in getting into the research on irradiated food? Did they have any requirement for irradiated food?

General MACLAUGHLIN. I can answer that, sir. Back in 1954–55, when this program was given some impetus, we had to have a requirement for this effort. In the area of future feeding of the future Army, with the possibilities of the change of the type of battlefield and all of the conditions with which I am sure you are familiar and which we visualize in a possible future war, a requirement existed for a simplified type of feeding. We have always had the purpose of giving the soldier the best possible food we could give him under any circumstances. Our past experience showed that we could not always give every soldier in every location of the battle field the best possible food.

Representative PRICE. Does the Army now consider that this requirement no longer exists?

General MACLAUGHLIN. The requirement for that particular purpose still exists that I have just briefly outlined. There is a need for simplified foods in the best possible form. We felt irradiation was a means of providing a so-called simplified food in the best possible form, the closest to natural fresh food.

Representative PRICE. There is a degree in the use of the word "urgent"?

General MACLAUGHLIN. Yes, sir.

Representative PRICE. The urgent requirement would be only when the actual emergency arose.

General MACLAUGHLIN. That is right.

Representative PRICE. Then you would not have the time to do the research and development.

General MACLAUGHLIN. That is right.

Mr. MORSE. No, sir; I don't think I would agree with that.

Representative PRICE. How can you disagree with it? The urgent requirement would be an immediate requirement. Of course, you could not do this on an immediate basis. You have been working on it about 8 or 9 years and have not accomplished it. So when the urgent requirement existed, you could not be expected to do it overnight.

Mr. MORSE. I think I was using the term "urgent" in a different sense from that which you apparently are. It is a question of semantics. Either in wartime, either general or limited war, the urgency or let us say the dire necessity for acquiring irradiated food is not as severe as a great many other requirements we have in the Army. I am not putting urgency in the sense of a time scale. I am putting it in a category versus other items, processes, the products and equipment, which the Army and the other two services need.

Representative PRICE. Who are you disagreeing with, me or the Army?

Mr. MORSE. I don't know. I merely tried to define my position, sir.

Chairman ANDERSON. Do you recognize any conflict between what you said and what the general said just a moment ago? Do you agree completely, both of you, on this subject?

Mr. MORSE. I think this is a question of degree. Would you agree with that, General, on the term "urgency"?

Chairman ANDERSON. This was not urgent. I thought this was a requirement.

Mr. MORSE. Sir, the Army has a requirement for all kinds of foods. They are doing an excellent job. They have improved their food supply. They have simplified packaging. They have dehydrated foods. They thought irradiated foods might supplement this diet. It would save money in terms of dollars of purchasing. We would save refrigeration costs. I certainly agree with the general that this was a logical program to implement. It just has not worked out the way we thought it was going to. At least the way I thought it might work out.

Representative VAN ZANDT. You agree with the general that there is a requirement?

Mr. MORSE. There is a requirement for a food product if it met the original specifications, and it does not.

Representative VAN ZANDT. Then, based on a subsequent statement, you give indications the priority of the requirement is a little lower than other needs of the Army; is that right?

Mr. MORSE. In my view this is true.

Representative VAN ZANDT. Have you been influenced in any way by the Bureau of the Budget?

Mr. MORSE. Everybody in the United States is influenced by the Bureau of the Budget. Everything we do in the Defense Department is essentially a matter for battling for dollars. I want to say, sir, this was not the primary consideration as far as I was concerned with respect to this decision.

Representative PRICE. The point is that as far as the Army is concerned, they still regard it as a requirement. The difference is now that you don't think you are ready to go ahead with the program as you originally conceived it?

Mr. MORSE. That is right. I think the general and I agree on that. Is that correct, General?

General MACLAUGHLIN. Yes, sir.

Chairman ANDERSON. Do you agree, General?

General MACLAUGHLIN. Yes; I agree in essence with what Mr. Morse has said here. The requirement still exists for the type feeding that I outlined a moment ago. That is our agreement, there is a need for that type of food. The Quartermaster General's position is still that since he is responsible for the feeding of the Army, that requirement is still placed upon him to satisfy that so-called basic requirement. So we agree on that.

Chairman ANDERSON. I only want to put in the record, you mentioned these two devices that you had, the linear accelerator. With whom is that contracted?

Mr. MORSE. Varian Associates of Palo Alto, Calif.

Chairman ANDERSON. Is there any connection between Stanford University and your work?

Mr. MORSE. Stanford University has been a contractor on this program, but not in connection with that unit as far as I know.

Chairman ANDERSON. The head of the physics department is chairman of the board of Varian Associates. We had that in connection with the $105 million they wanted for the Stanford accelerator.

Mr. MORSE. I was not aware of that.

Chairman ANDERSON. You were not aware of the fact that a man from Stanford is chairman of the board of Varian Associates?

Mr. MORSE. I am not surprised, but I was not aware of it.

Chairman ANDERSON. But somebody from Stanford did work with you on this program?

Mr. MORSE. Stanford has in the past had numerous contracts in this field. Isn't that correct, General?

General MACLAUGHLIN. I can't speak to the specifics of that.

Dr. SIU. Stanford has had some contracts.

Mr. MORSE. Yes; not substantial ones.

Chairman ANDERSON. Did it have a contract that led up to the development of the linear accelerator?

Mr. MORSE. I can't answer that, Mr. Chairman. Perhaps Dr. Siu can answer that.

Dr. SIU. I do not believe this particular contract on the Varian accelerator was based on any decision involving anybody we know of from Stanford.

Chairman ANDERSON. Stanford gets a royalty from all the klystron tubes sold by Varian Associates. I can't tell you who it is, because I can't now remember, but the head of the physics department is chairman of the board of Varian Associates.

Mr. MORSE. Stanford has a contract amounting to about $18,000 a year in this area. This is a measurement of radioisomers. It is not associated with design and construction.

Representative VAN ZANDT. Mr. Morse, we have established the fact that the Army has a requirement for irradiated food. If my memory serves me correctly, a moment ago you said that the project needed additional laboratory work. What is this need based on?

Mr. MORSE. Sir, if I may go on here, I will answer that question. I am about to the point of saying why I took the position that the radiation center should be canceled.

Chairman ANDERSON. Go ahead.

Mr. MORSE. If I may divert one moment to be certain we understand this word "urgency," I still have a feeling that you and I are not in complete agreement. The Army has a requirement for a wholesome, good tasting, economical, easy transportable food product, meat being obviously of principal interest because it is the most expensive item in the Army's procurement budget in the food field. I suggest that if you think in terms of that as being an indication of urgency, you will perhaps see why the decision was made. We still have that requirement. In my view, this center would not have expediently met that requirement.

Shortly after assuming my duties as Director of Army Research and Development on June 1, 1959, I initiated a critical review of the Army's food irradiation program, the potential economic and logistical advantages, and the possible health hazards associated with the extended use of irradiated foods by humans. I was assisted and received advice and guidance in the medical aspects of this review by the Army Scientific Advisory Panel. After additional discussions with knowledgeable people in government and industry, I came to the conclusion that it was premature and not in the best interest of the Army or the taxpayer to proceed with construction of the proposed facility.

On September 10, 1959, I recommended to the Army Chief of Staff that all actions and plans, including further development of design drawings, specifications, and cost estimates related to constructing and equipping the Army Food Irradiation Center, be indefinitely suspended and that action be taken to terminate most effectively and economically all contracts connected with the establishment of the center. I further requested that a revised program, oriented toward fundamental studies in the field of food irradiation, be developed.

Chairman ANDERSON. Mr. Morse, would you supply us later on with the names of the individuals who are on the Army Scientific Advisory Panel for the record?

Mr. MORSE. The entire panel, sir?

Chairman ANDERSON. Yes. Was it not reviewed by the entire panel?

(The information referred to follows:)

PERSONS CONSULTED BY MR. MORSE RE VARIOUS ASPECTS OF THE FOOD IRRIDATION PROGRAM

Dr. Walter Nungester (Member, Army Scientific Advisory Panel), Director of Bacteriology, University of Michigan, Ann Arbor, Mich.

Dr. Stanhope Bayne-Jones (Member, Army Scientific Advisory Panel), Special Consultant to the Director of Health, Education, and Welfare.

OTHERS

Mr. James M. Hait, Executive Vice President, Food Machinery and Chemical Corp., Box 367, San Jose, Calif.

Lt. Gen. James M. Gavin (retired), Arthur D. Little, Inc., Acorn Park, Cambridge, Mass.

Dr. Carson Dalzell, Assistant to the Director of the Reactor Development Division, Atomic Energy Commission.

Mr. Michael Michaelis, Arthur D. Little Co., 30 Memorial Drive, Cambridge, Mass.
Mr. John R. Townsend, Special Assistant to the Director of Defense Research and Engineering, Department of Defense, room 3–E–1022, Pentagon.
Dr. Ralph Siu, Technical Director, Research and Engineering Division, Office of the Quartermaster General.
Brig. Gen. W. J. Ely, Director Army Research, Office of the Chief of Research and Development room 3–E–374, the Pentagon.
Gen. L. L. Lemnitzer, Chief of Staff, Department of the Army.
Colonel Hollingshorst, Deputy Commander, Medical Research and Development Command, Office of the Surgeon General.
Lt. Col. J. B. Hartgering, Medical and Biological Sciences Branch, Life Sciences Division, Office of the Chief of Research and Development.
Lt. Gen. R. W. Colglazier, Deputy Chief of Staff for Logistics, Department of the Army.
Mr. Paul E. Feucht, Deputy Assistant Secretary of the Army (Logistics), Department of the Army.
Mr. Emmet C. Cameron, vice president and general manager, Varian Associations.
Lt. Gen. L. D. Heaton, The Surgeon General, Department of the Army.
Maj. Gen. V. J. MacLaughlin, Asst. QMG for Operations, Office of the Quartermaster General.
General Calloway, Commanding General, QM R. & E. Command, Nadick, Mass.
Maj. Gen. A. T. McNamara, The Quartermaster General, Washington, D.C.
Hon. Herbert B. Loper, Assistant to the Secretary of Defense for Atomic Energy, Department of Defense.
Dr. Brunton, Curtiss-Wright, Plainsboro, N.J.
Mr. E. V. Wilson, executive vice president, Armour and Co., Chicago, Ill.
Col. R. H. Oliver, Army Research Office, Office of the Chief of Research and Development, Department of the Army.

Mr. MORSE. I am coming to the individuals. I have one of them here today.

Chairman ANDERSON. Then you said you had knowledgeable people that you discussed this with. If we could be given some indication of who those were, it would be helpful. Did you discuss this in any way with the Atomic Energy Commission when you reached this decision?

Mr. MORSE. Yes, sir.

Chairman ANDERSON. With whom there?

Mr. MORSE. This was not done in a formal manner. I think my first contact was with Mr. Dalzell, who is knowledgeable in the field of the cobalt 60 source. I wanted to get some information from him for my own education. At his suggestion I talked to Dr. Aebersold. My formal line of communication with the Atomic Energy Commission is through General Loper, who is the Atomic Energy Assistant to the Secretary of Defense. I discussed the subject with him. I indicated my feelings on the program as a whole. He stated that he would discuss the subject with Mr. Luedecke, the General Manager of the Atomic Energy Commission.

Chairman ANDERSON. I was only interested because I was wondering if Mr. McCone knew this prior to the cancellation.

Mr. MORSE. Mr. Chairman, I cannot answer that. I have had no direct contact with Mr. McCone. In my position I normally would not. My contact would be with General Loper.

Chairman ANDERSON. Why? He is the representative of the Department of Defense.

Mr. MORSE. He is in the Department of Defense and is the liaison with the Atomic Energy Commission.

Chairman ANDERSON. Then there was no real discussion with the Commission on this, was there? I am just trying to find out because I had the impression—I can't testify for Mr. McCone—that this came to him as quite a shock.

Mr. MORSE. Mr. Chairman, I can't speak for the Atomic Energy Commission. All I can indicate is the action which I took. This was to as soon as possible discuss the subject with General Loper who is the DOD adviser for atomic energy affairs. He is the normal channel I would go to in the Department of Defense. He indicated that he would discuss this with the Atomic Energy Commission. Normally in the system of the Pentagon, I certainly would not contact Mr. McCone. I think that would be out of order.

Mr. RAMEY. Would that be the way the technical basis for any decision would be arrived at, that you would do it through formal channels?

Mr. MORSE. Now, you are raising an entirely different question. At that time I had a technical assistant prior to Dr. Schwab joining my office, who was knowledgeable in this field, and he was working for me in connection with the question of induced radioactivity. This was one of the first subjects to which I directed my attention in early June. As a matter of fact, it was the second week after I took office. In this area he discussed the question in more detail with the individual technical people in the Atomic Energy Commission. I understood the chairman was speaking in terms of the Commission at a higher level and I was differentiating between the detailed technical discussion and the general discussions which I had with General Loper and with Dr. Aebersold. In both instances I indicated my general concern for the program as a whole, and the thinking I had on the subject.

Chairman ANDERSON. I was only interested in the fact that there are in existence some laboratories operated by the Atomic Energy Commission. One of those laboratories, at least, has probably had more experience with irradiation than all the rest of the laboratories put together, and it was not consulted. I am just trying to find out who you did talk to. I am not trying to misquote you. But you said you thought Loper might take it up with Luedecke.

Mr. MORSE. I thought he would.

Chairman ANDERSON. We had a situation where we found some different results in fallout in South American countries and Dr. Libby of the Atomic Energy Commission made a speech saying that he never heard about these new studies. So I am naturally interested if the information you had got to the Atomic Energy Commission.

Mr. MORSE. I wrote to General Luedecke on September 17. At that time I stated, based on my review of such considerations and not on the question of potential induced radioactivity, I believe the Army staff will shortly respond to my recommendations on the general subject of the Army's food irradiation center and its future.

Chairman ANDERSON. This was notice to General Luedecke after you had recommended discontinuance of the laboratory. I was asking who did you consult before you reached the decision.

Mr. MORSE. I discussed this with General Loper. I discussed it with Dr. Aebersold, their isotopes expert. I talking to Mr. Dalzell,

because I was concerned with the economics of cobalt 60. These three I remember specifically at the moment.

Representative VAN ZANDT. Mr. Morse, can you describe in a few words the extent of the AEC participation in this program?

Mr. MORSE In the general food irradiation program?

Representative VAN ZANDT. Yes.

Mr. MORSE. I think Dr. Siu is more qualified than I am. He has been with this program for many years. Dr. Siu, would you answer that generally?

Dr. SIU. The AEC has been extremely cooperative with us in the Army. I would like to take this opportunity of expressing our appreciation to the AEC. Beginning in 1953, there was a very smooth transition from the Atomic Energy Commission's program to the Army's. It was a very cordial and effective one. We took over their contractors and we jointly went forward.

Representative VAN ZANDT. In other words, the AEC passed on to the Army the responsibility for the R. & D. in this field?

Dr. SIU. That is correct, sir, except for the development of radiation sources, since they are the experts.

Mr. MORSE. We passed back funds to the AEC.

Chairman ANDERSON. Could I call to your attention a hearing that you had with the Subcommittee on Research and Development of the Joint Committee on Atomic Energy in 1956, in which there is a little paragraph on page 321 about intergovernmental collaboration:

> Following a series of briefings to various Government departments last year by an Army team, an Interdepartmental Committee on Radiation Reservation of Food has been formally organized, consisting of representatives from the Departments of State, Defense, Agriculture, Commerce, Health, Education, and Welfare, and the Atomic Energy Commission. This Committee will render a semiannual report to the President on the progress made—

and so forth.

So it was not just separate and distinct. It was not all passed on to the Army.

Mr. MORSE. No.

Dr. SIU. May I develop that picture? I think you are quite correct.

Chairman ANDERSON. Senator Aiken has a question.

Senator AIKEN. May I ask how the Army happened to undertake this research in the field of irradiation of foods? In the first place, was it the result of a legislative directive or executive directive, or how did the Army happen to be chosen as an agency to carry on this research work?

Mr. MORSE. Within the Department of Defense the Army was designated as the cognizant agent for this activity by the Research and Development Board of the Department of Defense.

Senator AIKEN. Then the Department of Defense directed it, with the cooperation and understanding and approval of other agencies of Government?

Mr. MORSE. I don't think normally the Army needs approval——

Senator AIKEN. I am wondering since the Army uses such a small part of the food supply of the Nation, why it was chosen. Was it chosen because it had the funds to do it and others did not?

General MACLAUGHLIN. Sir, the Department of the Army was chosen——

Senator AIKEN. Who was it chosen by?

General MACLAUGHLIN. Let me put it this way, sir. The Department of Army was designated as the Department of Defense's agency to carry on the research and development work because the Army historically has had the basic research and development effort for feeding of the Army for years and it had the know-how, the in-house scientific knowledge, and the facilities to embark on this program.

Senator AIKEN. You felt that the Army had greater know-how than the Department of Agriculture or Health, Education, and Welfare? I am just wondering why they happened to be chosen. I can see why the Department of Army would be chosen by the Department of Defense, but who told the Department of Defense to go ahead with this?

Mr. MORSE. Sir, all of the work in this field in the United States is not done by the Army. There are other interested agencies concerned with the general problem of food preservation.

Chairman ANDERSON. Wouldn't it be fair to say that the Atomic Energy Commission started work in this field in about 1950 and the Department of Defense said, "No, this is our responsibility." When it reached that conclusion, the Atomic Energy Commission had to drop its work. You shake your head. Are you sure you are shaking it right? If you do, I will just read from the report on this. This is Mr. Horner's testimony. As I remember, he was at one time connected with the Department of Defense.

Mr. MORSE. Yes, sir.

Chairman ANDERSON. Charles Horner, Division of Reactor Development. I am sorry. I think he was with the Atomic Energy Commission rather than the DOD. When he testified before the Subcommittee on Research and Development of the Joint Committee on Atomic Energy on May 9, 1955, he said:

Five years ago—

this is at page 35 of the "Radiation Sterilization of Foods," published in 1955—

the Atomic Energy Commission initiated research and development activities within its own laboratories and with universities to investgate and develop uses for fission products. The most promising use of this material at the present time is for food preservation.

Based on agreement between the Atomic Energy Commission and the Department of Defense, the Commission terminated in 1954 its support of food preservation work when the Army undertook its program.

When you start talking about these sudden increases in appropriations that is the time when the Atomic Energy Commission got out of the field and you got into it.

Mr. MORSE. Would you agree with that, Dr. Siu?

Dr. SIU. Yes, sir. May I say a few words? Your question, Why did the Army take over this specific project, why not Agriculture, or Health, Education and Welfare, or others, is a very good question. I was serving as liaison officer with the Department of Agriculture at the time. We had talked over with Agriculture and AEC from the standpoint of overall national good, which organization at that period of the development of this program should be the spearhead. It was agreed that the Atomic Energy Commisison had been the best one to take it up to that point. It seemed as if the next salient in this program was in food technology. The Atomic Energy Commission by

that time had accumulated enough data on the atomic energy side. The project now needed somebody on the food technology and on the medical side. Since the Army has a very good food technology laboratory, a very good collaborative relationship with the industry, a very good Food Advisory Committee in the Academy of Sciences, it was felt that if the Atomic Energy Commission remained the experts in atomic energy sources, then the Army can push the food aspect. The Army Surgeon General could work together with Health, Education, and Welfare to cover the medical side. This is the way the Army had mapped out its program. The Army agreed to take the next phase up to a reasonable point, when it can then throw the ball back to a governmentwide collaboration. Hence the establishment of the Interdepartmental Committee. The Army looks upon it as the group to phase the program from the Army to a broader governmentwide sponsorship, and then to private industry. That is how the Army entered the particular picture of food irradiation.

Chairman ANDERSON. Was this interdepartmental group consulted before the decision was reached to terminate the program?

Dr. SIU. That particular decision was made at the Army level, sir.

Chairman ANDERSON. I said was the Committee consulted?

Dr. SIU. I do not know, Senator. I will have to refer that question back to Mr. Morse.

Chairman ANDERSON. Was the Interdepartmental Committee on Radiation Preservation of Food consulted when this decision was made?

Mr. MORSE. I discussed the question with Mr. McCoy who was then Chairman of this Committee, and indicated to him my very grave concern in the light of very recent questions as to the wholesomeness of the product, and my questions with regard to the economic and logistical advantages of the product even if it were of excellent quality.

Subsequently Dr. Schwab and I discussed it with him at considerable detail at luncheon. We have since had a meeting of the Interagency Committee to review the findings of the Army and keep them informed as to why we made our decision.

Senator AIKEN. Mr. Chairman, may I ask what is probably the most elementary question that will be asked here? What is the difference between radiation of foods and irradiation of foods?

Mr. MORSE. I think one should say irradiation of foods.

Senator AIKEN. I know. They have been irradiating milk for the last 20 years. What is the difference between radiating foods and irradiating them?

Mr. MORSE. Sir, I don't have the benefit of a Harvard education, but I think in general one would use the verb "radiate" and the noun "irradiation." Is that correct? There is nothing new about irradiation, sir.

Senator AIKEN. I guess it is too elementary.

Chairman ANDERSON. You have the same difficulty.

Mr. MORSE. We have been irradiated since Adam and Eve.

Representative VAN ZANDT. Mr. Morse, I would like to conclude one point here, if we can. Other than talking to General Loper and several other employees of the AEC, the Atomic Energy Commission was not consulted prior to making your decision to suspend the program?

Mr. MORSE. Sir, I don't know what you mean by consulted. I talked to them. I wrote General Loper. I discussed with the technical people as did members of my staff the kinds of problems with which we were concerned. In that sense we certainly did consult. There was no mass conference or committee or meeting as one has in Washington to make a decision.

Representative VAN ZANDT. In other words, you did not ask the AEC whether they concurred or did not concur in your decision?

Mr. MORSE. That is correct.

Representative PRICE. Mr. Chairman, may I ask one question?

Mr. MORSE. I was told I was not required to do that, and I did not do it. They were asked to concur in the press release which was sent out so that they would approve the final release in the form in which it was released to the public and they did concur in it.

Representative VAN ZANDT. You say they did concur in the press release?

Mr. MORSE. Yes, sir.

Chairman ANDERSON. This will be interesting. What notice did the AEC have of your press release?

Mr. MORSE. They approved it. It is my understanding from the Chief of Information of the Army. Is there someone here that can confirm that?

Representative PRICE. Mr. Chairman, may I ask a question? Mr. Morse, you stated that when you came into this job, one of your first acts was to look into this program and to cause a critical review of it. Did you personally initiate this or did someone within the program come to you and state that they were having difficulties and that it should be looked into?

Mr. MORSE. This program has been confused and delayed continuously for a number of reasons, all of which at the time perhaps appeared logical. The actual decision to go ahead with the construction of the plant—funds required a decision at my level, because of the need to request release of funds from the Department of Defense. My predecessor, Dr. Martin, with whom I had worked for some time in the past 2 years, because I had been Chairman of the Army Science Advisory Panel, had hoped that he would reach a decision on this prior to my taking office. As a matter of fact, it was the one item to which he had been directing his major attention.

He was unable to arrive at a decision prior to my coming, and he indicated that this was one of the items of principal importance to which I should direct my attention and I did that the first day I arrived.

Representative PRICE. It was indicated to you by your predecessor in your position?

Mr. MORSE. Yes, sir.

Representative PRICE. That this should command your early attention?

Mr. MORSE. It had been delayed for some time. I was anxious to either go forward with the plant or stop it, and not continue to delay it.

Chairman ANDERSON. May we revert to the press story to clear up what was in our minds?

Mr. MORSE. Yes, sir.

Chairman ANDERSON. General Loper wrote a letter to Mr. Price, chairman of the Subcommittee on Research and Development of the Joint Committee, dated October 16, 1959, which replied to Representative Price's letter of August 11, 1959. We had been trying to find out for 2 months about this. General Loper in his letter said—

> the Department of Army has just informed me that the decision has been made to immediately suspend construction on the proposed Army Ionizing Radiation Center at Stockton, Calif. The reasons for reaching this decision are included in the attached brief which the Army intends to release to the press today.

General Loper, it seems, had just heard about this himself. He says "has just informed me of the decision" which they intended to release to the press that day. You check back some time and supply us with a statement whether that preliminary press release had been cleared with the Atomic Energy Commission, or whether it had not, because it contained a number of things that the Atomic Energy Commission subsequently made great objection to. It got its information from the newspapers. Copies of this had been released to them. You dragged back this press release and released a second one that cut out these things.

Mr. MORSE. Mr. Chairman, I don't think that is quite correct.

Chairman ANDERSON. That is interesting. What do you think?

Mr. MORSE. I think you are referring, according to my informant, to the preliminary draft of a press release which was sent to the Atomic Energy Commission, which contained certain information, particularly on the subject of the health hazards associated with animal feedings. They did not concur in releasing that information. Certain elements within the Army did not concur. This was not a release, sir, if I may say so. This was a draft.

Chairman ANDERSON. I just read you General Loper's letter. You say your work was done with him. I would be happy to have you take a look at it if you have a question. He said that the reasons for reaching this decision are included in the attached brief, which the Army intends to release to the press today.

When that got to the AEC, you got some kickback. You did not release it. You did draw it back, did you not?

Mr. MORSE. No, sir; not as I understand what you are saying.

Chairman ANDERSON. I am just telling you what the AEC tells us.

Mr. MORSE. All I can give you is my view on the subject, also, Mr. Chairman.

Chairman ANDERSON. General Loper makes the statement that you intended to release it to the press that day.

Mr. MORSE. What day was that?

Chairman ANDERSON. October 16.

Mr. MORSE. I think, Mr. Chairman, you are referring to a preliminary draft of October 16, which was not released. It never constituted a release. As far as I know there was only one copy which ever left the Army Office of Information. The actual release which we sent was October 22. It was altered, according to my understanding, to meet the concurrence of the Atomic Energy Commission and all the various levels within the Army, so that we all had a release which we considered was reasonable. That was October 22.

Chairman ANDERSON. Only one copy of this draft left the Army office?

Mr. MORSE. That is my understanding.

Chairman ANDERSON. It did not go to any newspaper?

Mr. MORSE. No, sir; that is what I have been told. If it did, it did not go from the Army.

Chairman ANDERSON. How do you suppose we got a copy of it?

Mr. MORSE. Things happen strangely in this town.

Chairman ANDERSON. How do you suppose the AEC got a copy of it? You could take one copy and reproduce it.

Mr. MORSE. Mr. Chairman, it was sent to them for coordination. The Army Information Office requested coordination from the AEC in the final release of October 22. That I believe you said was October 16, which was one of many drafts which we had. The October 22 release was the only actual release that I am aware of.

Chairman ANDERSON. I would be happy to have you look at it again. See if it says it is a preliminary draft or is it the "brief which the Army intends to release today."

Mr. MORSE. We did not. We did not send that draft out because the AEC did not concur, and neither did some elements in the Army.

Chairman ANDERSON. We have a note on our copy:

General Loper's office telephoned October 16, 1959 and advised it will not be released before Tuesday, October 20, at the earliest.

So apparently there was some hitch to it.

Mr. MORSE. The Atomic Energy Commission and certain people within the Army didn't like that draft release and we didn't send it out. If you would read the October 22 one, Mr. Chairman, you will find it is substantially different. I want to point out that at the press conference, of which we have a recording, we attempted to answer every single question that might have been raised if they had seen that release, and I believe we did a pretty good job of answering toxicity questions by medical people.

(General Loper's letter of October 16, 1959, and the proposed press release of October 16, 1959, follows:)

OFFICE OF THE SECRETARY OF DEFENSE,
Washington, D.C., October 16, 1959.

HON. MELVIN PRICE,
Chairman, Subcommittee on Research and Development, Joint Committee on Atomic Energy, Congress of the United States.

DEAR MR. CHAIRMAN: In reference to your letter of August 11, 1959, the Department of the Army has just informed me that a decision has been made to immediately suspend construction of the proposed Army Ionizing Radiation Center at Stockton, Calif. The reasons for reaching this decision are included in the attached brief which the Army intends to release to the press today.

I understand that the Department of the Army will place more emphasis upon continued laboratory research.

Sincerely,

HERBERT B. LOPER,
Assistant to the Secretary of Defense (Atomic Energy).

STATUS OF FOOD IRRADIATION PROGRAM

The Department of the Army today suspended indefinitely plans for construction of an irradiated food plant at the Sharpe General Depot, Stockton, Calif., pending further laboratory studies on the use of radiation as a means of preserving food.

Army officials said that although considerable progress has been made in the field of radiation preservation, it would be premature to proceed with the construction of the pilot plant until certain basic technical and economic questions about the process are answered at the laboratory level.

The plant was designed to develop production techniques, for irradiation of foods and to determine the best methods for attaining effective preservation. It was also intended to produce sufficient quantities of foods for testing of palatability and acceptability. Incidentally the cost of producing large amounts of irradiated food as compared with other methods of food preservation could be accurately determined.

So far, approximately $1.3 million has been spent on design planning and certain components for the project. Contract termination costs have not been computed as yet. Eventual cost of the finished plant has been figured at $7.5 million.

Private contractors affected by the suspension include Curtiss-Wright Corp., Princeton, N.J., and Varian Associates, Palto Alto, Calif.

Also affected is Irradiated Products, Inc., New York City, which was formed by four companies—Armour Co., Food Machinery & Chemical Co., General Foods Co., and Continental Can Co.—to perform at its own expense production planning for the plant. So far, Irradiated Products, Inc., has spent $133,000 in assisting the Government in the project.

When design work was started in 1957, it appeared fundamental problems in radiation preservation would be solved before the facility was due to be completed. The plant planning was started at that time to make possible a quick transition from laboratory studies to pilot plant studies.

Quick transition was deemed necessary to reduce leadtime—the time that elapses between the start of a development project and its final completion.

The Army began investigating radiation as a means of preserving food in 1953 as a part of President Eisenhower's atoms for peace program. The research effort has been under the direction of the Army Quartermaster Corps. The Army Surgeon General's Office has supervised medical aspects of the program. Private and public agencies, such as universities, have been assisting under contracts with the Army.

The process utilizes radiation to kill or control bacteria which cause food spoilage. Other methods of food preservation utilize such techniques as freezing, drying, refrigerating, and canning for the same end purposes—to kill or control bacteria.

Army officials said certain key problems have not yet yielded to solution in the laboratory. Furthermore, new problems have arisen.

Army officials said they were advised in reaching their decision to suspend the Stockton plans by military and civilian scientists.

The officials said two main considerations prompted the decision.

One consideration involves biological changes in some experimental animals.

Initially in the program, short-term animal feeding studies showed no ill effects. Based on these studies, short-term human feeding studies were undertaken and once again no ill effects were noted. Following this, long-term animal feeding studies were initiated.

The bulk of these latter experiments were encouraging. However, there has been recent evidence that some experimental animals which have been consuming irradiated food as a part of their diets in long-term, 2-year feeding studies have developed as yet unexplained biological changes.

It is not known if those changes resulted from long-term eating of irradiated food or if they resulted from some inherent peculiarity of the animals or of the experimental methods used. But Army officials said more basic laboratory studies are needed to find out conclusively if a causative relationship exists between the changes and irradiated food. It is not possible at this time to estimate the date by which these studies will produce definite results.

A few dogs fed certain irradiated foods as a part of their diets over a 2-year period have turned up with varying degrees of infertility. It is not known conclusively if the infertility is related in any way to the irradiated food. Scientists who did this work are now analyzing their data to determine if any conclusions can be drawn.

Other scientists have noted blindness occurring at a somewhat greater rate in some rats fed irradiated food as a part of their diets over a long-term, 2-year period than in control rats not given such food. However, the same group of workers in another series of experiments using rats found the blindness rates among test and control animals the same. Again, the finding is preliminary and it is not known if blindness is connected with the irradiated food.

Still other scientists have noted heart disorders in one experiment involving mice. These workers are now seeking to repeat the work.

Bleeding disorders have been observed in several centers doing long-term, 2-year feeding studies on rats. It is believed that this biological change is related to the way in which rats manufacture and absorb vitamin K.

Rats are not similar to humans in vitamin K manufacture and absorption and this phenomenon may bear no relationship to the effect of irradiated food diets in man. Vitamin K is important in body's blood-clotting mechanism.

The Army Surgeon General's Office in September analyzed all recent animal experiments and recommended further laboratory level studies. While none of the studies are conclusive and represent only preliminary findings, Army officials said that when they are taken altogether they indicate a valid reason for temporary suspension of construction plans on the Stockton pilot plant.

In the 5 years since irradiated food investigations began, some 200 human volunteers have eaten irradiated food as a part of their diets for short terms. In addition, interested observers, including some newspapermen, have eaten single meals consisting in part of irradiated foods. No biological changes associated with irradiated food have been noticed in these individuals, nor can they be anticipated on scientific grounds.

A sharp distinction should be drawn, Army officials said, between short-term feeding which covers periods of days or weeks and long-term feeding which covers periods of months and years.

A second consideration in canceling the Stockton work relates to the economic justification of irradiated food within the Military Establishment if and when the process proves feasible. Army officials said further careful studies are needed to show precisely how strategic and tactical advantages will be gained from the use of irradiated food.

For instance, packaging of irradiated food is a part of the overall logistic problem. Quarter master scientists have been working on packaging since early in the irradiated food program, but this problem has not yet yielded in final solution.

The Army program on radiation preservation of food called for the first 5 years, starting in 1953, to be spent making investigations at the laboratory level. A wide variety of food items including various meats, fruits, and vegetables were selected for research.

Laboratory studies during this time have been aimed at determining exactly how radiation affects the physical and chemical properties of these food items, as well as how radiation affects their nutritional value, wholesomeness, palatibility, and acceptability. In addition, studies have been carried out on suitability of various sources of radiation.

Foods used in the feeding studies originally were irradiated only at the materials testing reactor operated by the Atomic Energy Commission at Arco, Idaho. Two other locations for the irradiation of test food were added later. One is the Army Chemical Corps' Dugway, Utah, installation. The other is the Savannah River AEC facility in Georgia.

The Stockton project, known as the U.S. Army Ionizing Radiation Center (USAIRC), was designed to include two methods of irradiating food. One involved the use of a cobalt 60 gamma radiation source known as the high intensity food irradiator (HIFI). The other involved the use of a linear electron accelerator (LINAC).

Estimated costs of the completed plant include $4 million for the facility itself, $2.5 million for the HIFI and $1 million for the LINAC.

A $1.6 million contract for the HIFI, exclusive of cobalt costs, was awarded to Curtiss-Wright by the AEC which has been carrying out this phase of the program on behalf of the Army. Of this amount, approximately $350,000 has been spent.

Varian Associates, which has the contract for LINAC, has spent approximately $600,000.

Facility construction is under the direction of the Army Corps of Engineers. So far, about $375,000 has been spent on design drawings, specifications, test boring and other preliminary work.

(The Department of the Army press release of October 22, 1959, follows:)

DEPARTMENT OF THE ARMY,
OFFICE OF THE SECRETARY OF THE ARMY,
Washington, D.C., October 22, 1959.

Information for Members of Congress:

A public announcement, worded substantially as follows will be made today:

The Department of the Army today deferred plans for construction of a U.S. Army Ionizing Radiation Center at the Sharpe General Depot, Stockton, Calif., pending further laboratory studies on the use of high dose radiation as a means of sterilizing food.

Army officials said that, although considerable progress has been made in the field of radiation sterilization, it would be premature to proceed with construction of the USAIRC until certain basic technical and economic questions about the process are answered at the laboratory level. In the studies of irradiated food, Army emphasis has been in high dose sterilizing treatment leading to long-term storage of food without refrigeration. Major civilian and industrial interest is low dose treatment to extend shelf life. Technical and economic requirements for low dose treatment are not nearly so demanding as for high dose treatment.

The irradiated food program, Army officials said, will continue to be actively fostered at the research level.

The center was designed to develop production techniques for irradiation of foods and to determine the best methods for attaining effective sterilization. It was also intended to produce sufficient quantities of foods for testing of palatability and acceptability.

So far approximately $1.3 million has been spent on design planning and certain components for the project. Eventual cost of the finished plant has been figured at $7.5 million.

Private contractors affected by the suspension include Curtiss-Wright Corp., Princeton, N.J., and Varian Associates, Palo Alto, Calif.

Also affected is Irradiated Products, Inc., New York City, which was formed by four companies—Armour Co., Food Machinery & Chemical Co., General Foods Co., and Continental Can Co.—to perform at its own expense production planning for the plant. So far, Irradiated Products, Inc., has spent $133,000 in assisting the Government in the project.

When design work on the center was started in 1957, it appeared fundamental problems in radiation preservation would be solved before the facility was due to be completed. The plant planning was started at that time to make possible a quick transition from laboratory studies to pilot plant studies.

Quick transition was deemed necessary to reduce leadtime—the time that elapses between the start of a development project and its final completion.

The Army began investigation of radiation as a means of preserving food in 1953. The research effort has been under the direction of the Army Quartermaster Corps. The Army Surgeon General's Office has supervised medical aspects of the program. Private and public agencies, such as universities, have been assisting under contracts with the Army.

The process utilizes radiation to kill or control bacteria which cause food spoilage. Other methods of food sterilization utilize such techniques as freezing, drying, refrigerating and canning for the same end purposes—to kill or control bacteria.

The officials said two main considerations prompted the decision. One is that certain physiological problems have not yet yielded to solution in the laboratory.

A second consideration in suspending the Stockton work relates to the economic justification of irradiated food within the Military Establishment if and when the process proves feasible. Army officials said further careful studies are needed to show precisely how strategic and tactical advantages will be gained from the use of irradiated food.

For instance, packaging of irradiated food for military use is a part of the overall logistic problem. Quartermaster scientists have been working on packaging since early in the irradiated food program, but this problem has not yet yielded a final solution.

The Army program on radiation sterilization of food called for the first 5 years, starting in 1953, to be spent making investigations at the laboratory level. A wide variety of food items including various meats, fruits, and vegetables, were selected for research.

Laboratory studies during this time have been aimed primarily at determining exactly how high-dose radiation affects the physical and chemical properties of these food items as well as how radiation affects their nutritional value, wholesomeness, palatability and acceptability. In addition, studies have been carried out on suitability of various sources of radiation.

Foods used in the feeding studies originally were irradiated only at the materials testing reactor operated by the Atomic Energy Commission at Arco, Idaho. Two other locations for the irradiation of test food were added later. One is the Army Chemical Corps, Dugway, Utah, installations; the other is the Savannah River Atomic Energy Commission facility in Georgia. The Stockton project, known as the U.S. Army Ionizing Radiation Center (USAIRC), was designed to include two methods of irradiating food. One involved the use of a cobalt 60 gamma radiation source known as the high intensity food irradiator (HIFI), design of which was begun in July 1958. The other involved the use of a linear electron accelerator (LINAC).

Estimated costs of the completed plant include $4 million for the facility itself, including LINAC housing, $2.5 million for the HIFI, and $1 million for LINAC.

A $1.6 million contract for the HIFI, exclusive of cobalt costs, was awarded to Curtis-Wright by the Atomic Energy Commission which has been carrying out this phase of the program on behalf of the Army. Of this amount, approximately $350,000 has been spent. Varian Associates, which has the contract for LINAC has spent approximately $600,000.

Facility construction has been under the direction of the Army Corps of Engineers. So far about $375,000 has been spent on design drawings, specifications, test boring, and other preliminary work.

(Furnished by: Office, Chief of Legislative Liaison.)

Mr. MORSE. May I proceed, Mr. Chairman?

Chairman ANDERSON. Surely.

Mr. MORSE. On October 15, 1959, the Acting Chief of Staff, U.S. Army, in his memorandum to the Director of Research and Development stated that the Chief of Research and Development had completed a staff review of my recommendations of September 10 with respect to the Army's food irradiation program. This review confirmed my conclusion that construction of the U.S. Army Irradiation Center, as then conceived, was premature, that the program required reorientation, and that the Quartermaster General had been instructed to take appropriate action to terminate most economically all contracts for construction of the Army Irradiation Center and to prepare a revised research and development program.

The reasons for my decision were—

(*a*) No available studies confirmed any substantial economic advantage to the Armed Forces through the use of irradiated foods, nor was an urgent operational requirement established. Future logistical and operational advantages did seem possible with changing concepts of warfare and advanced technology and for this reason additional research as a part of the Armed Forces food research program appeared justified.

I felt it incumbent upon me to get as much outside opinion on this subject as possible. The Arthur D. Little Co. in Cambridge had been associated with the early phases of the Quartermaster program. They had competent cost-minded engineering people on their staff. I quote from a report which they prepared at my request, and which we used partially as a basis for our decision:

In light of current knowledge, there is no basis for choosing either frozen or irradiated meat to the exclusion of the other for military purposes; costs are about the same within the limits of accuracy of available data. The potential advantage of irradiated meat lies in the possibility of its making improved

rations available to combat troops. In the case of irradiated meat, freedom from the need for refirgerated storage and transportation may have logistic implications in military planning, entirely apart from cost considerations; for example, less rigid scheduling, greater ability to alter plans on short notice, and greater flexibility in transportation may have a substantial significance that our study could not take into consideration within the time available.

Chairman ANDERSON. Doesn't that more or less look like that might be promising?

Mr. MORSE. Potentially promising, yes, sir, but no economic advantage as had been previously thought.

Representative VAN ZANDT. Mr. Chairman, some of us on this committee have lived with this project for many years. Mr. Price has been the chairman of the subcommittee and hearings have been held each spring. The record will show that the Army, through their spokesman, from time to time have justified this program as being one that would save money for the Government in several areas. I am looking now at the hearings of 1956, when a spokesman for the Army outlined the program and in so doing makes mention of the fact that in fiscal 1960 or 1961, the program will have reached the point of perfection to where they are going to turn it over to private industry and the big packers of the country are going to take it over from that point on.

All of a sudden, the Army changes its position and now says, according to your statement, which is based on the study of Arthur D. Little, Inc., that there is no economic return whatsoever that can be expected from the program.

Chairman ANDERSON. Page 348, if you are hunting for it.

Representative PRICE. If the gentleman will yield, in the quote from the Arthur D. Little report that Mr. Morse has just read, the concluding sentence says this:

In the case of irradiated meat—

that would apply to other irradiated foods as well—

freedom from the need for refrigerated storage and transportation may have logistic implications for military plans.

This is the point the Army has continuously brought out and to me that would be a pretty big point.

Entirely apart from cost consideration, for example, less rigid scheduling, greater ability to alter plans on short notice, and greater flexibility of transportation may have a substantial significance that our study could not take into consideration because of availability of time.

This does not indicate to me that the Little report discounts the feasibility or the cost saving or the logistic advantage. This indicates to me that they gave great weight to it.

Chairman ANDERSON. Have they been given a chance to study this more since then? I have reference to Arthur Little. They said they had not had time before. Have they had time since?

Mr. MORSE. No, sir; they were not asked to do that. They were asked to investigate two things. I read directly from the report.

Question 1. Is the food irradiation facility as planned of the proper size to determine the engineering feasibility and practical economics of irradiated meats and to supply enough material for adequate field tests?

I asked them to investigate this because there had been criticism from various quarters that the plant was too big or was too small.

Comment. In our opinion a facility embodying U.S. Army Radiation Center concepts is necessary to insure the maintenance of representative industrial food handling practices and conditions. No other currently available irradiation facility seems adequate in this regard.

Chairman ANDERSON. Do I understand they did think it should have been built?

Mr. MORSE. Sir, I direct your attention that this question was whether this was the adequate size in order to determine commercial feasibility. Our problem here was, what is the most economical size plant that we might build which would give us the kind of handling data, cost data, production data, return on investment data, which would be adequate to subsequently induce industry to go in and produce meat. I doubt any of you gentlemen feel that the U.S. Army should go into the meat business. One of our problems was to get a plant of sufficient size to demonstrate the feasibility of the process.

Representative PRICE. That was the purpose of the Stockton Center. What was the report on that?

Mr. MORSE. This is what this is for.

Representative PRICE. The purpose of the Stockton Center was to determine this factor, was it not, the feasibility and size of the plant that you needed? That was the purpose. It was not a production plant.

Mr. MORSE. It would feed quite a few people. If necessary one could feed 100,000 troops with this plant.

Representative PRICE. Here is the purpose of the Stockton plant as given by the Army itself. It was given by Col. William D. Jackson, Chief, Office of Research and Development. That is the position you hold now; isn't it?

Mr. MORSE. No, sir; he is in the Quartermaster Corps.

Representative PRICE. This is Colonel Jackson's statement:

It has become increasingly evident that a facility must be constructed which will be capable of processing food on a pilot-plant scale in order to continue essential research and development study and to determine the economic feasibility of the process.

That was the purpose of the center.

Mr. MORSE. Yes, sir.

Representative PRICE. It was not a production plant.

Mr. MORSE. That is right. My question was whether or not this was a proper size to accomplish that mission and the Little Co. agreed that the Quartermaster Corps had sized the plant properly.

Representative PRICE. They agreed it was the proper size?

Mr. MORSE. Yes, sir. The second question to which we directed their attention was this——

Representative PRICE. Did they also agree it was essential to determine the economics of the process?

Mr. MORSE. No, sir.

Representative PRICE. That is, irradiation of foods.

Mr. MORSE. No, sir. I do not think they felt as strongly as the Army that it was necessary to build a plant of this size to solely determine the economics of the process.

Representative PRICE. Not solely. To conduct further research and development. It also would determine the economics of it.

Mr. MORSE. It would determine the economics, but you are not building a plant solely to get economic information.

Representative PRICE. No one says that. But to continue the full research and development of it, which would also determine the economics of it, and the economic feasibility of it.

Mr. MORSE. There are many aspects.

Representative PRICE. In other words, we are not talking about building a big construction plant out here. We are talking about a plant which the Army said was essential to continue this study.

Mr. MORSE. Yes, but the study, sir, included wholesomeness studies, feeding troops, supply problems, packaging.

Representative PRICE. All of which this plant was supposed to contribute to.

Mr. MORSE. That is correct. Little Co. agreed that the size was appropriate to accomplish all these missions.

Chairman ANDERSON. So they endorsed it?

Mr. MORSE. No, sir; they endorsed the size of the plant.

Chairman ANDERSON. Do you have a special report from Arthur Little?

Mr. MORSE. I have it right here.

Chairman ANDERSON. Have you furnished a copy to the committee?

Mr. MORSE. It is part of my presentation. The second question which we asked them was this.

Representative VAN ZANDT. What is the date of the Little report? When did you ask them to take on this project?

Mr. MORSE. Almost immediately after I took office.

Representative VAN ZANDT. When did you take office?

Mr. MORSE. June 1.

Representative VAN ZANDT. 1959?

Mr. MORSE. Yes, sir. I received a summary from them in early September, of their conclusions.

Chairman ANDERSON. When did you receive the report? What is the date of the report?

Mr. MORSE. We didn't receive the final typed report until December 11, 1959.

Chairman ANDERSON. You reached your decision in September 1959 anyhow?

Mr. MORSE. Yes, sir.

Chairman ANDERSON. Why did you have them give you a report?

Mr. MORSE. I had their conclusions. If I may continue I will read the second one.

Representative VAN ZANDT. Mr. Chairman, before we get into the second phase of it, may I ask Dr. Siu a question here?

Doctor, could you refresh at least my mind as to this overall program that the Army Quartermaster Corps developed, and which was presented by Colonel Jackson a few years ago? I have in mind the Fitzsimmons General Hospital experiment, then Camp Lee with 300 Army personnel, and eventually passing the project on to private concerns like Armour and others. Would you refresh our mind a bit as to that program which was presented to the committee?

Dr. SIU. As I recall, Mr. Van Zandt, there were three fundamental policy cornerstones from which we moved forward. The first was the concept of this particular project as an important part of the Nation's atoms-for-peace program. The country was emphasizing this. Your committee advised us to proceed as fast as we could to be sure that we

do not let the other countries show us their dust in this particular exploitation.

The second cornerstone was the collapsing of leadtime in military research and development, to meet the requirement that Mr. Morse and General MacLaughlin spoke about.

The third cornerstone was inherent in the Quartermaster General's responsibility as single manager of subsistence for the Department of Defense in which he would like to exploit every chance to improve the rations for the Army, Navy, and Air Force across the board as fast as he could.

Those were the three basic influences.

After the agreement among the Government agencies and AEC that the Army would spearhead the program, and following the hearings before your honorable group, we had mapped out the following approach. We felt that the relative objective must be the transition into industry at the earliest possible date for commercial production. That is the only way the Army will be able to buy a substantial amount of irradiated food. To do that, we must accomplish three things:

First of all, we must have a sufficient body of fundamental data from which industry and other people can carry on further research. What doses of radiation are necessary? How does the radiation affect different foods? Which foods are best? Which foods will be difficult? Which foods appear absolutely hopeless at a given stage of the development? How do you measure the amount of radiation received in foods? What guarantees must you use for insuring that foods are not radioactive? These questions represent the type of basic data required.

The second thing which we must have before industry would be willing to take over is the unequivocal clearance by the appropriate medical authorities. Does the Health, Education, and Welfare Department's Food and Drug Administration approve the process? Does the Surgeon General agree? Industry must have that unequivocal assurance.

The third thing which must be accomplished is the pivotal pilot-plant transition into industry. There must be a rough idea of the economic cost? I don't believe the various companies can be given a final figure because that depends on their own operations and their own individual interests. But can you give them a more accurate approximation than that obtainable from pure paper study? You can show a prospective bidder an actual sample as well as the actual operation of this novel type of processing.

Those are the three broad areas which we have emphasized. The question then is how fast do you want to move. We in the Quartermaster Corps had felt that we should move pretty fast, unless the signals are changed. We therefore paralleled phases of work. In other words, we were not completing all studies on atomic sources before we work on the chemistry of the process. Nor were we completing the latter before we work on toxicity, or other problems.

We set ahead of time a reasonable target date for industry to take over the process, at which time we would expect to procure a certain amount of irradiated food for the military. Then from that point backward we time-phased the respective work phases. A given work

phase was begun at the time estimated to be required considering the leadtime necessary for convergence at the target date. The first things to be started in 1953–54 were a substantial wholesomeness program, basic research, and a wide survey of all the foods across the board to determine which class of foods is most promising. When the meats looked as if they are pretty promising, and fitted in a general way with the military requirements, we began to activate such phases as packaging. When we considered the irradiation facility the question was at what date ahead of our target should planning and preliminary design studies be inaugurated. It was determined that these should be begun years ago hoping that we would make the time schedule as predetermined.

All of the work phases progressed along concurrently. We were aware of the difficulties under resolution in each of the phases at any given time. You never solve all of the problems. But our estimation has always been at any given time that we should move forward.

When we had moved to an appropriate point the Quartermaster Corps recommended the construction of the pilot plant. That plant was to be used for the research and development which Mr. Price spoke about, as well as the economics and feasibility studies which Mr. Morse mentioned. At the time of advancing the proposal we had not answered all of the questions in wholesomeness, nor all of the questions concerning the flavor of all foods. The important issue is, Do you judge that by the time you get the facility built and the bugs worked out that you would have answered the necessary questions? That is a matter of judgment, sir.

Chairman ANDERSON. Bugs is a bad term in this particular hearing.

Dr. SIU. Would you have a learned word for me, Mr. Senator?

Chairman ANDERSON. Problems, difficulties.

Dr. SIU. Difficulties, shall we say.

Chairman ANDERSON. Doctor, you found out that you could preserve chicken pretty well?

Dr. SIU. Yes, sir.

Chairman ANDERSON. And pork?

Dr. SIU. Yes, sir; and ham. We have made rapid progress.

Chairman ANDERSON. How do you know that you could not get it done by that time with the progress you were making on chicken and pork and various things?

Dr. SIU. The chicken, pork, and ham we know are of sufficiently good quality for the pilot plant. Beef is another food we are very interested in.

Chairman ANDERSON. That is a pretty fair guide.

Dr. SIU. The beef we are not sure on the quality but I feel we will have an acceptable product by that time. But the medical clearance which Dr. Youmans is here to go into details if you want, we have not finished that series of experiments. So that question is: Do you think that in 3 years you will overcome that hurdle, or do you not? Should we postpone the plant another year to get more solid information on these unresolved problems or should we go right ahead now? The Quartermaster Corps agreed upon postponement.

Representative PRICE. You say the Quartermaster Corps has agreed on postponement?

Dr. SIU. As of this date, yes, sir; because the Army decision has been made.

Representative PRICE. As a matter of curiosity, when they are working toward a decision of this sort, in this particular program how many people would you say would be so informed on it that they could make adequate recommendations on whether or not you are ready to go ahead with the construction of this plant when it would be needed? How many people would you say would be in that category?

Dr. SIU. I hesitate to state, sir, because some people have extremely acute judgment and on very limited data.

Representative PRICE. How many would be close enough to the project who would know the status of it and about when the need for the plant would occur?

Dr. SIU. If I give you the number, sir, you would ask for the names.

Representative PRICE. I am not going to ask you for the names. I would ask you what recommendation you personally made.

Dr. SIU. I personally had recommended going ahead.

Representative PRICE. You recommended going ahead?

Dr. SIU. Yes, sir.

Representative PRICE. Of all the people that you know that would know something about it, what would you think the percentage would be that recommended going ahead?

Dr. SIU. I would say of all the people who have some knowledge on which to express an opinion, 80 percent of them would be sitting on the fence very cautiously answering "Yes" or "No," depending upon who is asking them.

Representative PRICE. About those who had strong enough convictions not to worry about the budget, what would they recommend?

Dr. SIU. I would say at the time the decision was made, of the remaining 20 percent, three-quarters would say don't go forward.

Representative PRICE. Don't go forward?

Dr. SIU. That is correct, sir. I mean who will refuse to say positively move.

Chairman ANDERSON. You have me confused.

Dr. SIU. By "move" I mean going forward with the plant, sir.

Chairman ANDERSON. You said you would?

Dr. SIU. I would go forward, sir.

Chairman ANDERSON. Thank God you are here.

Dr. SIU. Thank you, sir.

Chairman ANDERSON. Yes.

Representative PRICE. You mentioned three-quarters of the 20 percent.

Dr. SIU. Would say, "Better stop, better wait."

Representative DURHAM. You are applying that statement entirely to the Quartermaster Corps, the 80 percent?

Dr. SIU. No, sir; this is considering everybody in this country.

Representative DURHAM. Would you include the Surgeon General's statement?

Dr. SIU. The Surgeon General took the position that he would comment only on the medical aspects.

Representative DURHAM. I wonder whether you were commenting on both the Quartermaster statement and the Surgeon General.

Mr. MORSE. Dr. Youmans is here from the Surgeon General. He is a medical doctor. We are getting into that phase shortly.

Representative DURHAM. I know you have not come to it yet.

Dr. SIU. I was commenting for the Quartermaster Corps which is in charge of the entire project which includes the work done by the Surgeon General, taking the Surgeon General's viewpoints into consideration, of course.

Representative DURHAM. Certainly you would not proceed or go ahead if the Surgeon General made a statement categorically that this was dangerous to feed the human beings.

Dr. SIU. If the Surgeon General has said there is a medical reason for stopping the program, I would have recommended stopping it. If the Surgeon General says, "I am not sure, we have not finished our research," then it depends upon a personal judgment as to how sure or how not sure. There is where your judgment comes into play, sir.

Representative VAN ZANDT. Dr. Siu, is it not true that over the period of years the activities that you described a moment ago were not alone Government-financed activities, but activities on the part of packers and the food handlers and processors of this country?

Dr. SIU. That is correct, sir.

Representative VAN ZANDT. Did they contribute to this program from the standpoint of dollars and cents?

Dr. SIU. I think the greatest contribution from the industry had been the generous lending of their advice and knowledge, and their facilities for trying out samples. There was no cost to the Government for much of industry's participation. Without that we would have been lost. In actual dollars, in proportion to the Government, the industrial expenditure has not been very high.

Representative VAN ZANDT. As the research progressed in this program, did you not have the advice of the medical fraternity from time to time?

Dr. SIU. Yes, sir.

Representative VAN ZANDT. At any time during the course of research, did you find that the medical fraternity took the position that toxicity had been left in the food that had been damaging to the human body?

Dr. SIU. Like anything in research you have a lot of discussions. I myself had never gotten the impression at any time that the medical authorities said there is medical reason for stopping the project. In other words, when you try to find out the wholesomeness of 21 different foods, you hit certain experimental, unexplained anomalies from time to time. I remember one of the early ones referred to a particular vegetable. The question arose—did radiation cause a slowing of growth in the animals? It turned out it was not due to irradiation at all. It was just due to something naturally present in that particular food.

While that question was unresolved, however, people separated into different zones of judgment. The extremely cautious would say, hold everything until that issue is resolved. This is the type of argument that goes on, sir.

Representative VAN ZANDT. Is it not true that at the Fitzsimons Hospital you fed irradiated food to volunteers?

Dr. SIU. Yes, sir.

Representative VAN ZANDT. You found no toxicity in their bodies as a result of continued tests even after they left the Fitzsimons General Hospital and returned home?

Dr. SIU. That is my understanding, sir.

Representative VAN ZANDT. Did you not feed irradiated food to officers and enlisted personnel of the Army, some 300, over a period of years?

Dr. SIU. Yes, sir.

Representative VAN. ZANDT. Did you find any toxicity in their bodies?

Dr. SIU. No, sir.

Representative VAN ZANDT. In other words, what I am trying to develop here is this: As this program proceeded you had the advice from not alone your associates in the Army Quartermaster Corps but the AEC, food handlers, and processors of the country, as well as other laboratories?

Dr. SIU. Yes, sir.

The Surgeon General's Office had good continuous advice from medical advisers throughout the country and from the Food and Drug Administration.

Representative VAN ZANDT. And to finance this effort the taxpayers spent something like $12 or $13 million.

Dr. SIU. That is correct, sir.

Representative VAN ZANDT. Let me go back to Mr. Morse. What are the qualifications of the Arthur D. Little Co., because here the findings of the Arthur D. Little Co., Inc., completely refute the findings of an effort spreading itself out over a period from 1953 to 1959 for which the taxpayers spent $13 million. I do not hesitate to tell you that some of us on this committee have been mighty enthusiastic about this program. We believe in Dr. Siu and his associates.

Mr. MORSE. So do I believe in Dr. Siu. Your question with respect to A. D. Little, I don't think is exactly correct. The request which we made to Arthur D. Little Co. was to purely look at the economic engineering aspects of the plant. I do not consider the A. D. Little Co. competent in the medical field at all. I am not competent. With the exception of Dr. Schwab, I don't think anybody in my office is competent to operate in this area.

In this area you need the medical profession. In my own experience when a physicist or chemist delves in the medical field he is in trouble. We requested the A. D. Little Co. to look at this plant from the point of view, first, its size, and second, the economics of the process.

Chairman ANDERSON. The size was all right?

Mr. MORSE. Yes, sir.

Chairman ANDERSON. How is the answer on the other one?

Mr. MORSE. May I answer it?

Chairman ANDERSON. Yes. It was all right, too?

Mr. MORSE. No, sir. Not in my judgment. Coming back to the dates, Mr. Chairman, you intimated or suggested the answer to the times as to when I approached A. D. Little and how I could arrive at a decision prior to the receipt of the report.

Chairman ANDERSON. We have all been through this, you know. There was a study made by the Loper committee at one time on the Rover project and the man from Standard Oil of New Jersey was in

charge of that program, Mr. Murphree. He was going to get his answer from the Loper committee and he got the committee's conclusions, but he decided the other way before they filed a report. I wondered if you were worried about their report and came to your conclusions ahead of their report. If so, why not wait until you get their report?

Mr. MORSE. Let me read from the letter I had from them on September 2 which answered the only two questions I was concerned with and the only subject to which I asked them to direct their attention. This was September 2.

Chairman ANDERSON. Why did they go on?

Mr. MORSE. They merely had not printed the report, Mr. Chairman. This was purely mechanics.

Chairman ANDERSON. Was it made available to this interdepartmental committee or AEC or to us?

Mr. MORSE. No, sir.

Chairman ANDERSON. It was not a secret document?

Mr. MORSE. No; it is not secret. This was made available to everybody the minute we had it.

Chairman ANDERSON. We have not seen it yet, even though we were going to have this hearing. Did you send us a copy when you heard about the hearing? The answer is "No"?

Representative PRICE. What was the reply to the two points?

Mr. MORSE. I read the first question, which we asked to direct their attention whether this size of the plant was appropriate. The second question, and these are the only two I wished to get from A. D. Little—Is there a significant logistic advantage for radiated meat in comparison with frozen meat, and, if any, what is the order of magnitude?

Conclusion: In terms of dollars, men, and material, the logistic advantages of irradiated meat are essentially counterbalanced by disadvantages when radiation economics are on a commercial basis.

Chairman ANDERSON. Does it say yes, a little; and no, not much?

Mr. MORSE. To me that says that irradiated foods on the basis of their analysis do not have economic advantage to the taxpayer versus frozen foods.

Chairman ANDERSON. Did he take into consideration just the food or did he take into consideration the great saving in refrigeration?

Mr. MORSE. This was based on the assumption that we would compare irradiated meat versus frozen meat, delivery, packaging, reasonable return on investment and depreciation of the plant.

Chairman ANDERSON. Did they look into fish?

Mr. MORSE. No, they were not asked.

Representative PRICE. How could they come to that conclusion when they said they didn't have time to take it into consideration within the time available?

Mr. MORSE. I think if you read a little more——

Representative PRICE. That is the last word. It says in case of irradiated meat, refrigerated storage and transportation may have logistic implications in the military plan entirely apart from the cost consideration, less rigid scheduling, greater ability to alter the plant at shorter notice, and so forth, may have a substantial significance that our study could not take into consideration within the time

available. I am not a member of that Arthur D. Little Co. or their study committee, but it seemed to me that has to touch economics.

Mr. MORSE. Sir, my experience with plants would indicate that you can prepare an economic analysis of a process at a relatively early stage if you are experienced in the field and the parameters are known. This sentence refers to the logistical implications of military planning, not the cost of running the plant.

Representative PRICE. That would apply also in commercial fields.

Mr. MORSE. No, sir; I don't think there is any comparison.

Representative PRICE. It would not be the same comparison, but there would have to be some because it would be the same on transportation flexibility. You would not need the refrigerated cars; you would not need the speed in transportation; there is some comparison.

Mr. MORSE. There is some comparison. But the Little report, if you read it in detail, refers to a comparison between the normal method of transporting frozen beef, and so forth.

Representative PRICE. Let me ask you this question: Since this was a military project essentially and the Army was involved in it, why would they have gone to the commercial aspects of it and not be given the time to study the logistics for the military?

Mr. MORSE. The military people were concerned with logistics. I discussed this question with the Deputy Chief of Staff for Operations. I discussed it with the Assistant Secretary for Logistics in the Army. These were the people to whom I referred my inquiries from the military point of view.

Representative PRICE. Did the military people say there was no economic feasibility involved here? Economics would not have the same consideration for the military as it would for the commercial; that is true. But if you have a lot easier logistic problem and if you have transportation flexibility, you would not need the speed in transportation. There is bound to be some type of savings, even for commercial.

Mr. MORSE. The problem we encounter here is a comparison between the fact that you don't need refrigeration. We have no saving in weight; we have no saving in size of packaging. Our packaging costs are higher for irradiated foods than they are for frozen meat. The plant investment is out of all proportion to a normal meat-packaging plant. If industry is to be interested in this field, and they certainly are not, based on anyone that I have discussed the subject with——

Representative PRICE. We have had expressions from the commercial users on this from time to time.

Mr. MORSE. Let us make certain——

Representative PRICE. As a matter of fact, we had at one time some groups that followed it closely.

Mr. MORSE. It is significant to note that industry at the moment is not spending any of its own money on this program.

Representative PRICE. That may be true, but they have been following it very closely.

Mr. MORSE. Yes, sir; they certainly have, as they should. Again I want to direct your attention to the fact that this plant was designed for complete sterilization of foods. I think it is important that you people realize this. A complete sterilization of food is not the same

as pasteurization. This country, as far as I know, is the only country in the world which has been spending any sums of money on complete sterilization of foods. There is a great deal of interest in terms of our atoms for peace program in pasteurizing foods with radiation. This means the use of low doses of irradiation. It could be useful. It would extend food shelf life. This may be very useful. This is an area in which I will quarrel with Dr. Siu. He recently made the statement that this plant should go forward. I question very much whether he really means the plant as currently designed to include the use of a 24 Mev accelerator, and a cobalt 60 source, for the production of a completely sterilized product such as we require for military use, these are not the products in my view or the view of the people with whom I discussed that this country needs or the underdeveloped countries of the world need.

This is, incidentally, also the viewpoint shared by our International Conference on the Preservation of Foods.

Chairman ANDERSON. What is that? Is that a private firm?

Mr. MORSE. Here, for example, is an article by Dr. Proctor of MIT who appeared before the International Conference on Preservation of Food. It was a NATO conference. This is the general difference in view between our country and other countries in the world. I want to emphasize that I am not unmindful of the need for this country to take the lead in the field of food irradiation. I would like to quote—and I am not prepared to say that he is a world expert—Dr. Henry Seligman, Deputy Director General of the International Atomic Energy Agency in Vienna.

Chairman ANDERSON. Who?

Mr. MORSE. Dr. Henry Seligman. This is on the peaceful applications of atomic energy:

> Another subject which is near to my heart in the Agency and perhaps even nearer to your heart is food irradiation. It is quite obvious that the use of big doses—namely, several million roentgens—to irradiate food has not proven very successful. A product is obtained which in most cases nobody wants to eat. The structure is changed and free radicals are formed. While some foods are less affected than others, generally one does not obtain a very good product. Therefore, the next approach is to irradiate with lower dosages and combine the radiation treatment with either heat or treatment or antibiotics or whatever one desires.

I think the Atomic Energy Commission or some members would concur in this general view as to the approach which should be made in terms of nonmilitary applications of food preservation, although I cannot speak for the Atomic Energy Commission.

Representative WESTLAND. I would like to ask this one question, Mr. Morse, along the line that Mr. Price was previously asking: It would seem that this Arthur D. Little report is not complete in that it did not consider as their report says, this matter of greater flexibility of transportation, less rigid scheduling and that sort of thing. Is it your intention to have this firm continue its study with those factors in mind and to make a report to you?

Mr. MORSE. No, sir.

Representative WESTLAND. I am inclined to agree with Mr. Price that it very well may have a little different aspect on this whole picture.

Mr. MORSE. I think the question of logistics is one to which the military itself can direct its attention. We have very considerable

competence within the Army. I think perhaps if I may go on with the other two reasons as to the decision——

Representative WESTLAND. No; I would like an answer to that question, Mr. Morse.

Mr. MORSE. My office has no current intention of additional assistance from A. D. Little, if that is your question.

Representative WESTLAND. You have no intention of having Arthur D. Little continue the investigation of this matter with those particular things in mind.

Mr. MORSE. Let me be sure I know the particular things.

Representative WESTLAND. The last sentence of the report which you include in your statement here.

Mr. MORSE. No, sir. I would say in that area the Quartermaster Corps and operations people within the Army would be more competent to make an analysis than Arthur D. Little.

Representative WESTLAND. Have they made an analysis?

Mr. MORSE. They have been directed to.

Representative WESTLAND. They have been directed to?

Mr. MORSE. Yes, sir.

Representative WESTLAND. That report has not been presented to you or anyone else, as yet?

Mr. MORSE. No, sir.

Representative WESTLAND. When that report is available, if it is not a classified document, can it be made available to the committee?

Mr. MORSE. Certainly. As far as I am aware, there is nothing in this area that is classified.

Representative BATES. I would like to ask Dr. Siu a question. Mr. Morse in his statement on economics said there are no available studies that confirm any substantial economic advantages. In 1956 when you were before the committee, Mr. Cole asked you whether or not there were economic advantages, and you said yes, they accrue in the amount of tens of dollars per soldier overseas, as a horseback estimate. Then later you were asked or Colonel Jackson was asked to incorporate in the record a figure that is a little bit more firm, and that was put in, which gave a military situation, including transportation, storage, spoilage, equipment, operation, making adjustments for the cost of radiation, packaging, and you come up with a figure of a saving of $40 per man overseas.

Dr. SIU. Per year.

Representative BATES. Per year.

Dr. SIU. Yes, sir.

Representative BATES. Do you still hold to that figure?

Dr. SIU. May I backtrack about a minute trying to set the ground for your question, sir.

Representative BATES. Set anything you want.

Dr. SIU. We feel this way in the Quartermaster Corps. There are certain areas where you cannot possibly get fresh meats into a battlefield because you cannot under the battlefield conditions move your refrigeration into the area. What has been the actual battle experience in the past is to move the refrigeration as far forward as you can for the morale purpose consistent with your logistical impediments. The question as to how much actually you save will depend upon what you estimate to be the place where you push this refrigeration supply chain. For each additional mile you push it, the expense on refriger-

ation is not the conventional cost of refrigeration but aggravated cost. So to come back to your question, if you consider the cost of refrigerated shipment on a normal basis, and compare that with irradiated food, into areas which you will normally push refrigeration without much difficulty, this has been the range of estimates to date. They vary downwards. How far down depends upon how far you push that factor. They vary from about even cost. In other words, some estimates, like the Arthur D. Little, taking the considerations in mind it will be about the same cost.

When you start calculating the other factors which have not gone into cost, and if you take into consideration in wartime pushing that refrigeration system to a farther point, and when you consider the loss factors involved if the refrigeration system that you push under wartime conditions falls apart, then the figure you come up with will be anyone's guess. The reason why I originally said, without going through a detailed study, tens of dollars, is because at that time we had the general estimate that it will certainly not be more expensive to gain the military advantages. It will not be more expensive, and we feel it will be cheaper. So I said tens of dollars per man per year. Now we went back and recalculated and guessed what we felt to be a reasonable estimate of additional cost, reasonable estimate of losses and so forth. I believe Colonel Jackson's office came up with a figure of $40 per man per year. The question is—is $40 per man per year a substantial saving a matter of judgment? That is where the situation lies at the present time.

In the Quartermaster Corps, we feel that we will not have to pay more to get food to where we normally cannot get it to troops.

Representative BATES. You were referring to an isolated combat condition?

Dr. SIU. Not only isolated. In modern warfare we envision a fluid war with people moving all around. Under those conditions we can not have refrigeration moved all around.

Representative BATES. You did not spell out in the insertion in here what you meant. You merely said one military situation.

Dr. SIU. Yes.

Representative BATES. But prior to that in your testimony you indicated this: That you would save tens of dollars per man per year overseas.

Dr. SIU. That is correct.

Representative BATES. For 1 million men overseas, it would be in the tens of millions of dollars per year. During World War II we had about 5 million men overseas.

Dr. SIU. That is right.

Representative BATES. The conclusion that one would draw from that, would be that for every individual overseas you would save so much per man. But you don't mean that.

Dr. SIU. I would say that tens of dollars per man overseas would be an average of an oversea man. That would be my guess. Now for some individual in the more forward area it would be more than tens. For some individuals right on the beachhead after D-plus-500 days it would be less.

Representative BATES. Let us take a peacetime operation in the cold war situation like we have today, would there be any savings?

Dr. SIU. This would be pure conjecture. As of this point I would say it would not be more expensive if we use our normal field equipment. If we use the refrigeration supplied commercially which had already been amortized and the additional cost is low, I would say it is still cheaper but I do not know how much cheaper.

Representative BATES. Did you read the Arthur D. Little report?

Dr. SIU. I have not read it in its entirety, no. I read that paragraph.

Representative BATES. Is that all you read?

Dr. SIU. Yes, sir.

Representative BATES. Then you could not comment upon its economic analysis.

Dr. SIU. No, sir.

Representative BATES. That is all, Mr. Chairman.

Representative VAN ZANDT. Doctor, did they call you in and ask your advice during the deliberations that took place prior to this decision being made?

Dr. SIU. Yes, sir. We had a lot of discussions.

Representative VAN ZANDT. I did not hear you.

Dr. SIU. I said we have had a lot of conferences and discussions.

Representative VAN ZANDT. You had your opportunity to participate?

Dr. SIU. Yes. Mr. Morse heard us real carefully.

Representative VAN ZANDT. Did you make your observations or present your views after you had a chance to read the Arthur D. Little report?

Dr. SIU. I have not read the report, sir.

Representative VAN ZANDT. You have not read the report?

Dr. SIU. No, sir.

Representative BATES. But you say under peacetime conditions this would not be more expensive?

Dr. SIU. Yes, sir; that is right.

Representative BATES. But you don't say you will save money under peacetime conditions overseas?

Dr. SIU. How much we save I would not know.

Representative BATES. How much you lose you do not know?

Dr. SIU. I don't believe we will lose money on this proposition. In other words, the Quartermaster position has been that you know you are going to get good food in certain places where you otherwise couldn't. In those places where you can, you are not going to lose money on it, so it is a good proposition.

Representative BATES. We are not selling this on the basis that for each man overseas we are going to save so much a year in peace or war.

Dr. SIU. No, sir. To establish a military requirement we do not set a miliary requirement on a sheer dollar and cents basis but on a tactical and strategic advantage at a reasonable cost.

Representative BATES. I understand that. But from reading the testimony before, it would indicate that is certainly one of the most important factors you were bringing to the attention of the committee, we were going to save $40 per man overseas.

Dr. SIU. It is an important factor but of secondary importance to the military.

Representative PRICE (presiding). Are there any further questions this morning?

Senator AIKEN. I am still a little disturbed over the general use of the word "radiation" or "irradiation." I find nowhere in the testimony any reference to the type of ray used in these experiments. I realize that there may be some editors around the country that don't know any more about radiation than I do and a lot of other people that may get the impression that irradiated foods are questionable as to their use. I think there should be in the record somewhere the type of ray used in the Army experiments which I understand is nuclear radiation.

Mr. MORSE. Senator, we have employed various kinds of irradiation sources—let me say radiation sources—and different kinds of rays to which you refer. One of the purposes of this radiation center was to make a decision with respect to which ray in fact one did find most economical, could be employed with safety, and would be used ultimately by industry. The center employed both a so-called cobalt 60 source, which essentially emits gamma rays, and a 24-million electron volt accelerator being made by Varian Associates which emitted electrons. Both of these are capable of producing irradiating materials and rendering them sterile, or rendering them pasteurized as the case may be, depending upon the level of dosage employed.

Senator AIKEN. You would not in any way question the safety of irradiated milk or other foods such as are sold and used extensively today?

Mr. MORSE. I have two other reasons for my decision for terminating the plant, and the third one involves potential health hazards which might arise as the result of using irradiated foods for humans.

Senator AIKEN. You question the use of the ultraviolet?

Mr. MORSE. No, sir; I would not as an individual.

Senator AIKEN. It is commonly used today, I believe. I can imagine if this thing goes far enough and the health and education and welfare goes far enough we may have a very emaciated populace.

Mr. MORSE. During the first week I took office this question of induced radioactivity was in my mind. We had a meeting with the representatives of the Quartermaster Corps, the Surgeon General, we had legal talent because we were concerned with the Food and Drug Act.

Senator AIKEN. I notice somewhere a reference to a higher percentage of rats being born blind. Are rats customarily born with their eyes open?

Representative VAN ZANDT. Mr. Chairman, before we get too far away from this part of Mr. Morse's statement, which has to do with the Arthur D. Little report, I would like to read into the record two other paragraphs that the Arthur D. Little Co. incorporate in their overall conclusion. This is page 3 of the report:

To the extent that irradiated meats are proved to be an improved ration, our study indicates that radiation sterilization of meat may equal or excel refrigeration as a technique of military feeding systems. It seems reasonable for military planners to foster research and development work on this subject and to try to interest commercial producers. The cost and circumstance associated with the project are such that commercial interests are unlikely to go forward on their own and Government initiative and financial support are required.

The second paragraph reads as follows:

If the Department of the Army has an overall interest in the military significance of irradiated food, it would be well to examine the cost of the use of irradiated food as the use of stockpile supply in the event of Zone of Interior disaster of considerable magnitude.

That is the end of the quotation.

Mr. MORSE. May I comment on that?

Representative VAN ZANDT. Yes.

Mr. MORSE. The major premise on which the Arthur D. Little report was written, and I tried to define it clearly so they did not waste a lot of time and money was first that the products produced were at least as good as normal food products from the point of view of taste and acceptability.

In case of meat, which is the product of major interest, this has not yet been achieved. Secondly, in the case of cobalt we could assume that cobalt 60 would be obtained as low as perhaps 50 cents per pound. I arrived at this figure after consultation with the Atomic Energy Commission. I believe the current price is $2 per pound.

I would also like to direct your attention to the fact that in the early first sentence of that statement it says "may." This is an implication that with additional research, and the advance of technology in its normal growth pattern in this country, there is a reasonable possibility that food irradiation will be successfully developed. I concur with that statement of A. D. Little.

Representative PRICE. From the little I heard from the Arthur D. Little report, and this is the first time it has come to our attention, it sounds to me like a rather favorable report for this project. We are talking about an installation here that is regarded as essential to prove out these things. So if the requirement still exists, and this center is regarded as essential to prove out the theory of irradiation of foods, it would appear to me that the Arthur D. Little report in effect supports the project.

Mr. MORSE. I want to emphasize that the position of the Army is to continue research in this field. We believe that the theory is fine, but it is not an appropriate time to proceed with a $7½ million plant in the light of the medical evidence we have and the none too obvious economic advantages.

Representative PRICE. In other words, that appears very worthwhile to do but this is not the time to do it.

Mr. MORSE. Yes, sir. Maybe we should not concern ourselves with the complete sterilization of foods from the point of view of the commercial field.

Representative PRICE. We now get back to the use of the word "urgency." When you are talking about a military requirement, the urgency is now, because you never know when you need these things. You cannot wait until the emergency arises to start the research and development or put the emphasis on acceleration.

Mr. Morse, we are barely half through your statement. The House is going into session now, so we will adjourn until 2 o'clock, when we will meet in the same room. You will be the first witness.

(Whereupon, at 12:05 p.m. the hearing was recessed, to reconvene at 2 p.m. the same day.)

AFTERNOON SESSION

Representative PRICE (presiding). The committee will be in order.

When we recessed this morning, Mr. Morse, you were continuing your testimony. If you are prepared, we will go on with your statement.

Mr. MORSE. Yes, sir.

I was outlining the three reasons as to why we arrived at a decision to terminate the construction of the Stockton facility. If I may, then, I will refer to the second reason, "b."

b. Since there was not an urgent operational requirement which was critical for the improvement of our Armed Forces capability to wage warfare, the Army was not justified in telescoping research, development, and piloting and taking the inherent risk to rush into a relatively large operation capable of full-scale feeding of troops prior to the completion of the research studies.

c. My review of the possible health problems associated with the consumption of irradiated foods also, at least raised sufficient doubt to demand a critical review of the process prior to proceeding with the then-contemplated plant. In memorandum dated September 1, 1959 to the Chief of Research and Development, the Army Surgeon General stated:

> Since January 1954 an extensive research effort has been carried on in animals and humans to determine the wholesomeness and toxicity of food preserved by irradiation. Acute toxicity studies and feeding trials were completed with no obvious evidence of harmful effects.
>
> In preparation of long-term feeding experiments in humans, the entire program of long-term animal feeding experiments is currently under review. In this preliminary review, there are definite questions raised, some of which may have a simple and logical explanation unrelated to the irradiated food, but there is definite indication that much additional research must be conducted in order to identify the nature and cause of the changes produced by long-term feeding to animals.
>
> Certain problems which warrant further study and research are the following:
>
> (*a*) Lowered fertility or sterility in dogs.
> (*b*) Hemorrhagic syndrome in rats.
> (*c*) Dilation and rupture of the left auricle in mice.
> (*d*) Blindness in rats.
>
> Until further clarification of these observed abnormalities can be made, extended human feeding tests and trials cannot be instituted.
>
> It would appear that short-term, closely controlled human feeding experiments and acceptability tests may well be warranted in view of the additional information which can be obtained.
>
> It is estimated that approximately 2 years of additional research effort will be required to satisfy the questions which have been raised. This is exclusive of sterility studies or of studies of ingestion of induced radioactivity with its possible long-term genetic effects. Such studies are conservatively estimated as requiring a minimum of 5 years before this food processing technique could be unequivocally approved.

Considering this information, on September 1 I established an advisory group of medical experts from the Army Scientific Advisory Panel to review this problem. This ad hoc group included Dr. Walter J. Nungester, professor and chairman of the department of bacteriology, University of Michigan, and Dr. Stanhope Bayne-Jones, Department of Health, Education, and Welfare.

They immediately came to Washington, and actually Dr. Bayne-Jones was in Washington, and they met the following day. This ad hoc group concluded, and I quote from their report to me:

Although animal feeding experiments with irradiated food were begun in 1954, it was not until about January 1959 that evidence was reported at meetings of investigators at Highland Park, Ill., indicating that irradiated foods may have toxic and pathological effects in animals when ingested over a long period of time. These findings, which have resulted from the program of chronic toxicity studies, were reviewed for us particularly by Col. L. Hursh, MC, who has been monitoring, for the Surgeon General, the medical and health phases of the study.

Representative PRICE. Could these reports be supplied for the record?

Mr. MORSE. Yes, sir. I believe I have quoted the entire letter right here, but we will send you copies. (See app. 2, p. 254.)

After considerable discussion it appeared to us that the data were somewhat equivocal except the dilatation and rupture of the left auricle in mice. As this lesion appeared to be statistically significant, we called Dr. Monsen, professor of anatomy at the University of Illinois, who alone among investigators had observed it. Briefly Dr. Monsen said that the dilation and rupture of the left auricle had occurred in only the first experiment, but that in a subsequent experiment during the period of February to September 1959, it had not occurred again. He is investigating it further and has not yet reached a definite conclusion as to the relation of the feeding of irradiated food to the production of the lesion.

Your ad hoc committee recognizes the difficulties and variables in such an extensive biological experiment as this one on the feeding of irradiated foods, and recognizes also the uncertainties in attempts to apply to human beings the results of experiments on lower animals. After listening to the presentations and discussions, we concluded that while there are indications that toxic effects may be produced by prolonged feeding of animals with irradiated foods, the results are not sufficiently definite to serve as a basis for accepting or rejecting irradiated food as a possible component of the military ration.

We are in agreement with the position of the Surgeon General so expressed in his memoradum of September 1, 1959, paraphrased as follows:

(*a*) Further animal experimentation should be conducted to verify and elucidate toxic pathological effects observed thus far and to search for possible additional effects.

(*b*) Short-term, closely controlled human feeding experiments are needed and warranted to determine acceptability and nutritional values.

(*c*) Extended feeding of irradiated foods to human beings is not warranted at present. A staged, progressive series of such tests should precede unrestricted use of this ration.

(*d*) The research program should be continued and extended, if necessary.

We also have here today Dr. Youmans, chief scientist of the Surgeon General, and Dr. Nungester, who was active in this study, if you care to question them.

It should be stressed that results of the long-term animal feeding studies are not completed and the anomalies reported to date are probably not due to irradiated food; however, since these findings have been reported, it would not be logical to feed irradiated foods over long periods of time to members of the Armed Forces until these anomalies have been proven not to be due to irradiated food. The completion of these tests may take from 3 to 5 years. The Army plans to continue support of a basic program required for such studies.

There are other problems associated with the development of a satisfactory end product which must be solved before we are justified in expending large sums of funds for pilot plant production operations. These are:

1. Development of procedures for improving the taste and odor of irradiated foods.

2. The identification of chemical changes.

3. Studies on the mechanism of proteolytic enzyme reaction and procedures for controlling the proteolytic enzymatic action on meats.

4. Studies on the mechanism of destruction of micro-organisms and the determination of the optimum dosage required for the destruction of resistant micro-organisms.

5. Development of suitable packaging materials and methods.

These problems as well as others must be solved prior to the initiation of large-scale operations. It is not advisable to expend large sums for pilot plant work prior to the completion of basic and applied research in this field, particularly in the light of the nominal economic and logistical advantages that appear to be inherent in the present process. This is particularly true with an entirely new and complex item such as irradiated food, which must pass the most stringent safety test prior to standardization and use.

As I stated above, I have directed that a revised program be developed toward the fundamental studies required to solve these and other problems.

The decision to suspend the construction of the center was released to the press at a press conference held on October 22, 1959. At this conference every effort was made to fully answer all aspects of the Army's decision. Appropriate representatives were available from the Atomic Energy Commission, the Office of the Quartermaster General, the Office of the Surgeon General, etc., and health questions were handled by qualified medical experts. It is unfortunate that a few of the press statements indicated that anomalies observed in animals had resulted from the feeding of irradiated foods, when, in fact, it was stressed at the press conference that these findings, while disturbing, were premature and inconclusive. It was specifically stated that additional long-range feeding studies, perhaps requiring from 3 to 5 years, would be required prior to approval of irradiated food as a subsistence item for the Armed Forces.

Since 1953 the Army has conducted a comprehensive program on the research and development aspects of irradiated food. These results will be of considerable value to the overall national and international program. The results of these studies, as well as all future work will continue to be made available to all interested people here and abroad. I believe that low-dose radiation for prolonging the shelf life of certain foods will have an important role in the civilian food industry within a reasonable length of time. The Army will continue to cooperate with industry and will maintain close working relationships with the Atomic Energy Commission, and other governmental agencies working on the irradiation of foods.

The Army's currently contemplated reoriented program will concentrate on high-dose sterilization while the primary civilian application is low-dose pasteurization of foods to extend shelf life. The problems associated with development of a satisfactory process for the complete sterilization of meats are much more complex and time consuming than those associated with low-dose pasteurization of foods required to extend the shelf life of various refrigerated foods such as seafoods, fruits and vegetables. These two programs are complementary; however, the detailed objectives and problems are considerably different.

52249—60—pt. 1——4

The Army will continue to cooperate with the various governmental agencies, educational institutions, and industry on this program and will establish a procedure for close liaison with the Atomic Energy Commission in the field of irradiated food.

I am confident that, in this brief statement, I have not been able to answer many of the questions in which you have expressed an interest. I would be pleased to attempt to answer any questions which you may have and to furnish, for the record, additional information on those which I may not be able to answer to your complete satisfaction at this time.

Representative PRICE. Mr. Morse, on page 4 of your statement I asked you if you have that report for the record. You stated the letter you were reading from was quoted almost in full, and leaving the intimation that this was the evidence, but you said in your quote at the bottom of the page—

it was not until about January of 1959 that evidence was reported at meetings of investigators at Highland Park, Ill., indicating that irradiated foods may have toxic and pathological effects in animals when ingested over a long period of time.

This is the material that I would like to have for the record. The evidence which you referred to is what I would like to have.

Mr. MORSE. Yes, sir.

(The material furnished by Mr. Morse will be found in appendix 2, p. 254.)

Representative PRICE. Any questions?

Mr. MORSE. May I have Dr. Youmans and Dr. Nungester clarify my position or give such additional information as they have as medical experts in this field? I am not a medical expert and I believe they are the people who should testify. I refer to my original statement as to the potential dangers that might exist, even though the date is inconclusive.

Representative PRICE. All right.

Mr. MORSE. Dr. Youmans, would you please express your views on this subject as representing the Surgeon General?

Dr. YOUMANS. Surely, Mr. Morse, I will be glad to.

With your permission, I would like to lay a little groundwork first. When this responsibility was laid on the Army Surgeon General and a comprehensive program of research expected to extend over about 5 years was laid out to determine the wholesomeness and toxicity, if any, and nutritional adequacy and the possible potential for induction of cancer of this food.

Now, that program has not been completed and on occasions like this, when questions are asked regarding some of these matters, all that can be given are conditional answers because the final answer has not been arrived at.

Representative PRICE. When was this supposed to be completed?

Dr. YOUMANS. Roughly in about 5 or 6 years.

Representative PRICE. What would be the final date?

Dr. YOUMANS. It was 1959 or 1960 that it would be completed.

Representative PRICE. How long do you think it will be before it is completed?

Dr. YOUMANS. Now, with the revised program, it will probably extend 2 or 3 years beyond the present time. I can give you the reason

for that, if you want. The reason is that it deals with the problem of some fertility or lack of fertility in dogs and you cannot breed sufficient number of dogs in a shorter time in order to determine how many of them are going to conceive.

Representative PRICE. Perhaps you can respond to this question, then. On page 5:

> After listening to the discussions, we concluded that while there are indications that toxic effects may be produced by long feeding of animals with irradiated food.

Would you give us some examples of those cases? What were the indications as to the effect that might be produced?

Dr. YOUMANS. The toxic effect, you mean?

Representative PRICE. Yes.

Dr. YOUMANS. The indications were such things as are listed on the page, I believe, preceding that. They were the fertility question that I mentioned, and this hemorrhagic disease in rats or the results in rats, and this dilation of the left auricle of the heart, and this blindness in rats which someone objected to this morning because rats aren't born with their eyes open, but they do have some difficulties with their eyes.

Now, those are the four principal findings which suggest, unsupported and not confirmed, but suggested possible toxic action.

Representative PRICE. Are you suggesting this as a result of your irradiated food?

Dr. YOUMANS. It occurs when the irradiated food is fed, and it does not necessarily follow it is the result of irradiation per se.

Representative PRICE. It occurs in other cases when ordinary foods are given?

Dr. YOUMANS. Yes, sir; it may.

Representative PRICE. So you cannot specifically tie it to irradiated foods?

Dr. YOUMANS. No, sir. All you can tie it to is the conditions under which the animals were fed, and it includes the fact that the food was irradiated and it includes the kinds of food, and it includes all of those factors, how they were cared for and the whole thing.

Representative PRICE. In other words, these effects which were being observed would not be uncharacteristic of animals on a diet made up of other foods, where the heat from the cooking process affected vitamins and other constituents.

Dr. YOUMANS. You can get deficiency in diet by other treatment than irradiation.

Representative VAN ZANDT. How much recognition did you give to the AEC's position as far as the adverse physiological effects of radiation of preserved foods on animals?

Dr. YOUMANS. I am not sure I can answer that, and I don't know what their position is.

Representative VAN ZANDT. Under date of November 19, 1959, we have a pretty broad statement here in which they differ considerably with the decision of the Army Quartermaster Corps. That is as to the technical basis of the decision.

Mr. RAMEY. This is a letter dated November 19, signed by General Manager A. R. Luedecke, to the Joint Committee, and it says it is in response to our request for information. It says:

2. With respect to possible adverse physiological effects of radiation-preserved food, the weight of present evidence indicates that any such effects observed to date in experimental animals are not the result of the consumption of the irradiated food per se. It is to be specifically noted that—

(*a*) Physiological effects observed occurred in an extremely limited number of animals and are not statistically meaningful.

(*b*) Considerable question exists regarding the scientific adequacy of many experiments conducted in terms of animal tests and control groups maintained, diets established, etc.

(*c*) The adverse physiological effects being observed would not be uncharacteristic in animals maintained on a diet largely made up of boiled meat, for example, where the heat from the cooking process breaks down vitamins and other essential dietary constituents.

(The letter referred to follows together with letters requesting the information:)

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C., October 27, 1959.

Gen. A. R. LUEDECKE,
General Manager, U.S. Atomic Energy Commission,
Washington, D.C.

DEAR GENERAL LUEDECKE: The Joint Committee would appreciate the Commission's comments on the recent deferral of the food irradiation project at Stockton, Calif.

The committee would be particularly interested in a review of the alleged scientific basis of this action.

Sincerely yours,

JAMES T. RAMEY, *Executive Director.*

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C., October 28, 1959.

Gen. A. R. LUEDECKE,
General Manager, U.S. Atomic Energy Commission,
Washington, D.C.

DEAR GENERAL LUEDECKE: With reference to the recent deferral by the Defense Department of the food irradiation facility projects at Stockton, Calif., it would be appreciated if the Commission would inform the committee of the disposition of funds authorized for the AEC portion of this project in fiscal 1957.

(Project 57–c–6)

The committee would also appreciate receiving information on the Commission's plans for the food irradiation program following the deferral of the Stockton project.

Sincerely yours,

JAMES T. RAMEY, *Executive Director.*

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., November 19, 1959.

MR. JAMES T. RAMEY,
Executive Director,
Joint Committee on Atomic Energy,
Congress of the United States.

DEAR MR. RAMEY: This responds to your letters of October 27 and 28, 1959, in which you request comments by the Commission on—

(1) the recent action by the Department of the Army to defer construction of the U.S. Army Ionizing Radiation Center, Stockton, Calif., with particular reference to the stated scientific basis for this action,

(2) the disposition of the $3 million in AEC funds involved in AEC–DOD projects 57–c–6, food irradiation facility, and

(3) the Commission's plans for the food irradiation program following the deferral of the Stockton project.

The following remarks are presented in response to the specific questions raised by you.

1. The Department of the Army arrived at its decision for deferral of the radiation center without prior consultation with the AEC. Based upon the Commission's knowledge in this matter, however, the Department of the Army's decision was predicated upon the fact that—

(*a*) Certain physiological problems have not yielded to solution in the laboratory. These include the questions of possible effects of radiation-preserved foods on fertility, vision, and the cardiovascular system.

(*b*) A current need exists for critical reevaluation of present economic justification of radiation-preserved food within the Military Establishment to show precisely how strategic and tactical advantages will accrue to the Army from the use of radiation-preserved food.

2. With respect to possible adverse physiological effects of radiation-preserved food, the weight of present evidence indicates that any such effects observed to date in experimental animals are not the result of the consumption of the irradiated food per se. It is to be specifically noted that—

(*a*) Physiological effects observed occurred in an extremely limited number of animals and are not statistically meaningful.

(*b*) Considerable question exists regarding the scientific adequacy of many experiments conducted in terms of animal tests and control groups maintained, diets established, etc.

(*c*) The adverse physiological effects being observed would not be uncharacteristic in animals maintained on a diet largely made up of boiled meat, for example, where the heat from the cooking process breaks down vitamins and other essential dietary constituents.

3. The Commission has been advised by the Army Quartermaster Corps that it is to proceed with the cobalt 60 high-intensity food irradiator project which the Army funded as follows:

(*a*) The contract which the Commission has with the Curtiss-Wright Corp. to design, construct, and test-operate the HIFI be continued with minimal effort.

(*b*) Cobalt 60 production by AEC for the HIFI be deferred until the radiation source requirements for the revised program are determined.

(*c*) The design phase of the HIFI work now in progress be continued pending a review of source requirements.

In the meantime, the Army is redetermining need for and type of radiation facility required to support the redefined research program for radiation preservation of food now being developed. The Army Quartermaster Corps has requested the Commission to provide recommendations by November 10, 1959, on a modified gamma radiation facility to support the food research program.

4. Project 57–c–6, food irradiation reactor (FIR), was abandoned because the Department of Defense favored a cobalt 60 food irradiation facility to be funded entirely by that Department. This project was rescinded by Public Law 85–590, dated August 4, 1958. Reference is also made to the letter of March 18, 1958, from the Chairman, AEC, to the chairman, JCAE, regarding the project. Funds appropriated to the AEC were reflected in the carryover available for application to the fiscal year 1959 requirements.

5. It is our opinion that the most significant civilian application of radiation to preserve food, both from a technical and economic viewpoint, is low-dose treatment to extend shelf life of perishable foods. In the United States and a large portion of the world, food losses are most substantial in the chain of supply between the producer and consumer. Emphasis under the Army program has been on high-dose sterilizing treatment for long-term storage without refrigeration.

Accordingly, we believe that serious consideration should be given to reorientation of the national program for radiation preservation of food with a focus on low-dose treatment. The Commission staff will present this viewpoint to the Interdepartmental Committee on Radiation Preservation of Food for consideration at its meeting on November 24, 1959. The objective of this approach would be to develop within the framework of the Interdepartmental committee elements of a revised national program and individual agency responsibilities.

Sincerely yours,

A. R. LUEDECKE, *General Manager.*

Dr. YOUMANS. I would agree with the first half of that statement, that there is no final evidence that the irradiated food is responsible for these findings. But as long as the uncertainty exists, we cannot give a clear bill of health.

Now, the second part, with regard to the design of experiments, I will have to disagree because these experiments were set up after consultation with competent people including members of the AEC and including Food and Drug Administration, and including Health, Education, and Welfare, and including our Committee on Nutrition of the Surgeon General, and including in particular a consultation with the statisticians of the University of Chicago, so these were well-designed experiments.

Senator HICKENLOOPER. I don't necessarily see anything incompatible about this. I don't read this quite that way. The wording here is:

> Considerable question exists regarding the scientific adequacy of many experiments conducted in terms of animal tests and control groups maintained.

At least, I would read that, that we were not necessarily questioning the methods but they might have reference to the adequacy of the extent of the tests to give any reliable answers.

Dr. YOUMANS. You mean, sir, the number of animals, or the number of tests taken?

Senator HICKENLOOPER. I do not know. Perhaps there is a sharp disagreement there. However, I would not read that as saying that the tests were not along the right line, but might refer to the fact that they might need 5 years more of tests rather than to draw a conclusion upon what has been done thus far, and therefore they are not adequate up to date. I don't know whether that is what they mean or not.

Dr. YOUMANS. That is possible, and that is what we say—that they are still not completed.

Senator HICKENLOOPER. There may or may not be any disagreement between the two of you on that statement.

Dr. YOUMANS. Yes, sir.

Mr. RAMEY. There is one further question along this line: Would it be necessary in order to get a scientific basis, that you be able to distinguish between the effects of irradiation and that of boiling, for example?

As I recall, there was some mention of the effects on vitamins, and it is well known that boiled heat affects vitamins, no matter where it comes from. In order to be a scientific basis for saying it is irradiation, you would have to have that controlled experiment that would say, "This is due to irradiation."

Dr. YOUMANS. Yes, sir; and we have done that.

May I give you an example. There is no question but that the hemorrhagic symptoms which occurred in rats fed the beef is a result of a lack of vitamin K. The lack of vitamin K is a complex one and it is a fact that the rat eats his own feces in order to supply vitamin K. Now, the feces which result from feeding this irradiated beef are not very tasty to the rat and so he does not eat his own feces and therefore suffers from a deficiency of vitamin K. We found that out, that is the explanation for it, and naturally in feeding humans the vitamin K could be supplied. In each one of these problems, we have taken

it back to find out what causes it, and most of them or many of them have been solved.

I can give you an earlier one if you would like. We found early in the course of experiments that feeding spinach caused trouble in experimental animals. The trouble was not due to the spinach itself or the irradiation or I should say it is not due to the irradiation, but because spinach contains high amounts of oxalic acid, which does not go very well with animals and it caused some trouble.

Mr. RAMEY. On your first example, that does not show the effects of irradiation, as such, does it?

Dr. YOUMANS. The only way you could determine that by experiment would be to eliminate all of the other possible causes.

Mr. MORSE. I would like to emphasize my statement, Mr. Chairman, to the effect that questions of toxicity at least raised sufficient doubt. I don't think that there is any disagreement between any experiments in this field but we have some big red flags raised here which certainly in my judgment precluded going ahead. This apparently is the view of the Surgeon General's office and I would like to have Dr. Nungester, who did represent our senior scientific advisory group, who is a medical doctor, comment further, if Dr. Youmans is through.

Dr. YOUMANS. I am through unless there are further questions.

Representative VAN ZANDT. Mr. Morse, continuing our discussion this morning about the decision and its release, I must confess that I am further confused as a result of what you say on page 6. You say that the decision to suspend the construction of the center was released to the press at a press conference held on the 22d of October 1959:

> At this conference every effort was made to fully answer all aspects of the Army's decision. Appropriate representatives were available from the Atomic Energy Commission, etc., and health questions were handled by qualified medical experts.

In this letter of November 19, signed by Mr. Luedecke, the General Manager, and addressed to Mr. Ramey, the executive director of the Joint Committee, it says this:

> 1. The Department of the Army arrived at its decision for deferral of the radiation center without prior consultation with the AEC. Based upon the Commission's knowledge in this matter, however, the Department of the Army's decision was predicated upon the fact that—

And then it breaks down the response why you took the position which you have already read into the record.

Now, on one hand you say that the AEC had some knowledge because they had representatives present, and on the other hand the AEC denies that they were consulted beforehand or knew anything about the decision.

Mr. MORSE. Well, now, who is the Commission?

Representative VAN ZANDT. It is the General Manager, General Luedecke, who signs the letter.

Mr. MORSE. I do not wish to imply that we had unanimity of opinion between the Army and the Atomic Energy Commission with respect to the decision. We had concurrence of the Atomic Energy Commission with respect to the release which we sent out. This was done prior to the sending of the release to the press, and Dr. Aebersold was present at the press conference, representing the Atomic Energy Com-

mission, and in a position to answer such technical questions as might arise and I believe he actually had a press release himself prepared prior to the release to the public. What I am trying to do is differentiate between whether they knew of the decision or whether they were in fact a party to it.

As far as I know, they were not in fact a party to the final decision, but we had conversations with the technical people earlier in June when I first took office. The initial technical problem which was on the horizon was a question of whether we did or did not have radioactivity in food. As of June 1, the day I arrived in Washington, this was a real question. We had a problem as to whether the food was radioactive after irradiation, and whether it was sufficiently radioactive to preclude approval of Food and Drug Administration for example. During the early phases of my investigation of this program, it was that area to which I directed my attention.

During that period, we had constant and continuing discussions with the technical people in the AEC, and I wrote to Mr. Luedecke on the subject requesting him to review information which we had generated within the Army.

Representative VAN ZANDT. What is the date of that request?

Mr. MORSE. August 21. At that time I was interested in getting the views of the Atomic Energy Commission as to whether they did or did not concur with the views which we were generating on the subject of induced radioactivity. Now if I may read from that, that is to General Luedecke:

> The Army expects shortly to complete a review of the technical, economic, and military use factors of the program on irradiation and sterilization of foods. This review will serve as a basis for decision regarding construction of the U.S. Army Ionizing Radiation Center at Stockton, Calif.

Dr. Edson, in my office, who was more qualified than I in this field, went into some detail and as a matter of fact it was in this letter of August 21 to General Luedecke——

Representative VAN ZANDT. Did you receive a reply to that letter?

Mr. MORSE. Yes, sir.

I can supply that for the record. General Luedecke essentially concurred with our view that, from the point of view of induced radioactivity solely, it was the view of the Atomic Energy Commission that the Army was on sound ground to proceed with the plant.

(The matter referred to is as follows:)

DEPARTMENT OF THE ARMY,
Washington, D.C., August 23, 1959.

Re radiological safety for the consumption of irradiated foods.

Gen. A. R. LUEDECKE,
General Manager, Atomic Energy Commission,
Washington, D.C.

DEAR GENERAL LUEDECKE: The Army expects shortly to complete a review of the technical, economic, and military use factors in the program on irradiation sterilization of foods. This review will serve as a basis for decision regarding construction of the U.S. Army Ionizing Radiation Center at Stockton, Calif.

Because of the current interest in interpretation of Public Law 85-929, pertaining to the irradiation of foods, we have carefully considered information available to us regarding the radiological safety of the consumption of irradiated foods. Key documents, together with a summary, pertaining to this matter are attached.

Our program of radiological measurement of irradiated foods is, of course, continuing. However, we have concluded that, from the standpoint of prudent

judgment based on the quantitative measurements now available, there exists no scientific reason for a policy alteration of the Army food irradiation program arising from considerations of induced radiation in the food.

The Army requests Atomic Energy Commission comment upon, or concurrence in, this conclusion.

Sincerely,

RICHARD S. MORSE,
Director of Research and Development.

SUMMARY OF THE SITUATION RE INDUCTION OF ACTIVITY IN IRRADIATED FOODS, AUGUST 21, 1959

Since the earliest days of the radiation preservation of foods project, personnel working in the area have been cognizant of the potential problem of radioactivity in food.

"In small amounts, radiation is a phenomenon of nature to which every living creature is subject. Cosmic rays from outer space, gamma radiation from radium and its radioactive decay products in the earth's crust, an alpha, beta, and gamma radiation from radium and the radioactive isotopes of hydrogen, carbon, and potassium which occur naturally in food and in the human body combine to give body tissues an average radiation dose equivalent to about one-tenth of a roentgen of X-rays per year." [1]

Under certain conditions, ionizing radiations may induce additional radioactivity in food. The amount added is so small that 2 hours after irradiation, induced radioactivity has never been directly measured in food exposed to 5 megarad of gamma rays or electron beams up to 16 Mev, although efforts have been made by at least five outstanding laboratories using most advanced counting techniques.

With 24 Mev electrons (not contemplated for foods at this time) the amount of activity added when treating food to 5 megarad is so small that, with the exception of Na^{22}, enrichment of the food in food elements or chemical concentration of the food after irradiation is necessary for detection. The consumption of a full diet of food sterilized with 24 Mev electrons (an extreme condition) may theoretically add one one-thousandth of a roentgen of X-rays per year.

The direct interaction of food elements with gamma rays below 2.2 Mev can add radioactivity only by the forming of certain isomers. At least three attempts by reputable laboratories have failed to detect radioactivity added as a result of this reaction in food irradiated up to 10 megarad with Co^{60}. The instruments used are sensitive to at least 0.3 disintegration per min. Where spent reactor fuel rods are employed as a source of radiation, some neutron production can be expected from the reaction with deuterium and gamma rays with energies over 2.2 Mev. In existing sources neutron fluxes range between 7 and 2X103/cm^2/sec. From these measurements the maximum amount of added radioactivity can be calculated to be about 10^{-6} microcuries/gram. Strenuous efforts to actually detect the induced activity have failed to provide any position measurement. The most recent authoritative report concluded that "Measurements of radioactivity of typical foodstuffs after pile irradiation, and of the particular isotopes concerned, indicate that sterilization in a flux of 10^9 thermal neutrons is an entirely safe procedure, particularly if a few days' cooling is allowed. After 100 days' cooling the radioactivity of typical foodstuffs is negligible by any criteria." [2]

Research work in the area of added radioactivity in foods sterilized with gamma rays and electrons is continuing with extensive efforts to directly measure activity resulting from many nuclear reactions; first in every common element occurring in foods and then in many foods themselves.

---

[1] Dunham, Charles L., "Fallout—One of Several Sources of Radiation Exposure to the Total Population."

[2] Gustafson, Philip F., Brar, S.S., and Brues, Austin M., "Activation Products in Foodstuffs Irradiated With Thermal Neutrons."

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., August 31, 1959.

DR. RICHARD S. MORSE,
Director of Research and Development, Department of the Army, Washington, D.C.

DEAR DR. MORSE: Thank you very much for giving us an opportunity to review the very complete package of material on the present situation with respect to "Induction of Activity in Irradiated Foods," dated August 21, 1959.

The staff of the Division of Biology and Medicine has studied the data which you have submitted and concurs in your general conclusion that "from the standpoint of prudent judgment based on the quantitative measurements now available, there exists no scientific reason for a policy alternation of the Army food irradiation program arising from considerations of induced radiation in the food."

We will, of course, be happy to receive any further data you develop on the subject as we have a very real interest in your program.

Sincerely yours,

(Signed) A. R. LUEDECKE,
General Manager.

Representative VAN ZANDT. Mr. Chairman, at this point could we ask a representative of the AEC if they might clarify this question as to whether or not they did have knowledge of the decision, that is, advance knowledge of the press release.

Representative PRICE. Is there anyone here from the Commission who would want to answer that? Commissioner Floberg, do you have a statement? Do you have any information on that point?

Mr. FLOBERG. I think that I can summarize it, although this is hearsay from the staff.

Representative PRICE. Would you come over here, please.

Mr. FLOBERG. I think that I can summarize the situation on the basis of the information which the staff has furnished to me, although I was not personally a party to any of these discussions or this correspondence. I believe that it is proper to say that the AEC was well aware from the time shortly after Mr. Morse came into the Army, that this whole field was under very active review, and I think that there were consultations between the AEC staff level people and the Army staff level people with regard to the program in various respects. I think it is also fair to say that the Army's decision was made by the Army independently of the AEC and of course it was their responsibility to make any such decision as it was not an AEC program. They had conferred at the staff level with the AEC, but there was no coordination of the decision itself with the AEC. I believe that is an accurate statement.

Representative VAN ZANDT. What about the press release?

Mr. FLOBERG. We furnished the letter of August 31 and I have a copy here right now, in case you want to have it read into the record.

Mr. MORSE. The answer came to me on August 31, with respect to induced radioactivity which was the initial subject with which I was concerned, but this was not the primary consideration with respect to the decision.

On 19 October we had a conference in my office to discuss and mutually draft an acceptable press release, and representatives of the AEC, Quartermaster Corps, Chief of Information, Surgeon General's office were present.

On 20 October, the Defense Department forwarded after having obtained clearance from the point of view of security, the press release to appropriate hands.

On the 21st of October, the AEC Public Information Office, I believe Mr. Salisbury, gave us oral approval from the point of view of the AEC, that it was satisfactory. This did not mean that they concurred in the decision but concurred in the release which was subsequently sent out and we had press conferences on 22 October, and Dr. Aebersold represented the Atomic Energy Commission and sat beside me and we answered every question we could to the press. (See p. 22.)

Mr. RAMEY. Could I ask a question?

Do you know that the AEC knew on October 15 that you were going to issue the release on October 16?

Mr. MORSE. I have no knowledge of that.

Mr. RAMEY. Could Dr. Aebersold comment on that?

Dr. AEBERSOLD. I have the whole chronology here, which I would introduce.

Representative PRICE. Will you give it it us?

Dr. AEBERSOLD. The Quartermaster Corps Liaison Officer informed the AEC on October 15 of the possibility of an Army press release on Friday, October 16, announcing indefinite suspension of the USAIRC, which was the Stockton facility. The AEC through the military liaison committee, General Loper, requested delay in the press announcement or the deferral of it pending an opportunity for the Commission to comment on the Army action and the public announcement.

Subsequent to that, on October 19, we had this meeting where I was present and Dr. Dunham, to review the press release. It was stated by Dr. Schwab at the beginning of the meeting that we were not to comment on the decision or to consider the decision itself, but to review and consider the press announcement.

Mr. RAMEY. Did you initially object to the press release?

Dr. AEBERSOLD. Yes, sir. The press release that was read to us over the phone on the morning of October 16 which was ready for release that afternoon, we did not concur in because of some of the statements made concerning the wholesomeness which in regard to evidence available to the AEC we could not concur in.

Mr. MORSE. May I point out on October 20 I talked with General Loper, who I again remind you from my own point of view, and I am not trying to dodge responsibility, is my normal channel to the Atomic Energy Commission. I called him on October 20 and I gave him my general position and thinking which we had with regard to the plant, and the impending decision which I felt probably would be forthcoming, that I still had to advise the Secretary of the Army and the Chief of Staff, and determine whether they concurred in my viewpoint. They subsequently did.

May I ask Dr. Nungester, who represents the Army Advisory Panel, to comment on the medical aspects of this program?

Representative ASPINALL. Before the doctor makes his statement, I have come in to this afternoon's hearing a few minutes late and was not here this morning for which tardiness, I apologize. It is the time element that bothers me in this particular matter. Who was in charge of this program from 1950 to 1955, when I understand Dr. Martin took over?

Mr. MORSE. Well, now, I don't know what you mean by "who was in charge."

Representative ASPINALL. Who was the Director, if there was a director? Who was responsible for the program?

Mr. MORSE. If you are asking me who was in charge of research of the Army, I would have difficulty in answering the question. The Army had cognizance of this program within the Department of Defense, and the Chief of Staff of the Army had designated the Quartermaster Corps as having a primary responsibility for the program.

Representative ASPINALL. Dr. Martin was the Director from 1955 until 1959 when you came in?

Mr. MORSE. I believe that is correct.

Representative ASPINALL. If I understand your statement correctly, you took charge on June 1, 1959 and within 1 or 2 days after that you made your determination.

Mr. MORSE. Yes, sir.

Representative ASPINALL. That determination was that the program should be discontinued as far as the Stockton, Calif., operation was concerned?

Mr. MORSE. That is correct.

Representative ASPINALL. And within 35 days after that, the Chief of Staff concurred in your position, is that correct?

Mr. MORSE. I think that that is essentially correct, and I don't know about the 35 days.

Representative ASPINALL. Now, what bothers me is, what was happening preceding your incumbency in the position which you now hold? How was it possible for you to make your determinations that the program was no longer possible of fulfillment and yet up to the time that you took over, seemingly no one was advised of some of these problems that you found present. Can you answer that or am I asking you something that is not in your knowledge?

Mr. MORSE. I don't think that I can speak for my predecessor on how he operated. He advised me that this was a very difficult problem, it was one which was perhaps gray rather than black and white. I suspect that I probably was a little more aggressive in getting some advice and opinion and views as to what was going on in the field.

You might further say, I was unable to find anyone who had made what I would call a business engineering economic study of this program, and the economics of the process. This was done, and secondly, I think out of fairness to all of the people concerned prior to my taking the job, new medical information was being generated in the long-term animal feeding experiments which was not known to Dr. Martins and was not then known to me until I got into this thing pretty heavily.

Representative ASPINALL. Just 3 years prior to that, the Army appeared before this committee and asked for this authority; isn't that correct?

Mr. MORSE. That is my understanding, but I must say, from the medical point of view, we were continually generating information. The short-term feeding experiments looked fine, and the long-term feeding experiments—and I am aware of the difficulties—had not been completed. We were continuing to generate information, and I would like Dr. Nungester to give you a better view of this. This is his specific field, and I have found that people who are not medical

experts will do well not to comment on the kinds of problems with which one is confronted in that area.

Representative ASPINALL. I don't even allow myself to think about them as far as that is concerned. On the other hand, I do understand the difficulty that arises at the present time, when the action came so quickly after you took over, when apparently those in charge had not assumed the responsibility of advising the committee or the public as to what was taking place during those preceding 3 years.

Mr. MORSE. I don't think that that is completely correct. The Atomic Energy Commission and people concerned certainly knew that there were lots of areas of doubt in the program. They were not conclusive, but they certainly were areas where we were treading in fields which had not been explored previously.

Mr. ASPINALL. That is all right. You don't need to go into it any further. I was making a statement of my difficulty of understanding.

Mr. MORSE. I don't think 3 months is a very short time to make a decision in a case like this. That is from the economic viewpoint.

Representative VAN ZANDT. Mr. Morse, have you had experience in the food processing or handling field?

Mr. MORSE. In the past I have had some although I am certainly not an expert. My experience has been more from process development, from business or economic analysis of pilot plants and going through to completion. I am not a medical man, I am not a bacteriologist but I have been around the fringes of these activities in the past.

Representative VAN ZANDT. Let's go back to 1956, during the hearings entitled "Progress Report on Atomic Energy Research in Medicine, Biology, Agriculture, and Food Preservation." This is the Army's presentation on radiation and preservation of food, before the Subcommittee on Research and Development of the Joint Committee on Atomic Energy. They say this: "Promise looks brighter than ever" (p. 342).

I continue to quote:

> Given continued strong support from this subcommittee and other legislative and executive leaders, we have every hope that this will arrive within the foreseeable future (p. 344).

Representative ASPINALL. Would my colleague yield further on that very point? On August 25, 1959, Brig. Gen. C. G. DODGE, Deputy Chief of Legislative Liaison, Office of the Secretary of the Army, wrote to the Honorable John J. McFall, a Representative from California, the following letter, and I quote:

> The Secretary of the Army has asked me to reply to your inquiry concerning the status of plans for construction of the U.S. Army Radiation Center.
>
> The Secretary and his staff are very interested in the radiation preservation of food program and the potential value to the civilians and military of the food preserved in this manner. Progress has been substantial and encouraging and the program is now ready for the pilot-plant testing phase. The Army continually strives to reduce the time consumed between development and production of new items; however, since pilot-plant testing is the point at which substantial additional expenditures will be required, it is necessary that a thorough review of the program be made prior to entering this phase.
>
> Although this review has been underway for several months, and many of the questionable areas have been resolved, the overall review has not been completed.
>
> The Army is unable at this time to predict when the review and evaluation will be completed; however, upon completion and if favorable, the Army will request final approval for construction of the center from the Department of

Defense. You are assured that every effort is being made to expedite these matters and that you will be informed as soon as the decision is made.

Your continued personal interest and support of the radiation preservation of food program is appreciated.

That letter was dated August 25.

As I understand it, Mr. Morse, your final decision was made just a few days thereafter.

Mr. MORSE. I had never seen that letter to the best of my knowledge and so I can't comment on it.

Representative ASPINALL. It is just such matters as this that cause us a little difficulty, also.

Mr. MORSE. I would be very confused if I sat in your position. I can assure you that on June 2, I was confused. I am not now as far as this program is concerned.

Representative VAN ZANDT. I have one more question, Mr. Morse.

In your statement, the third from the last paragraph, you talk about the reoriented program, that it will concentrate on high-dosage sterilization of food. Has this program been launched?

Mr. MORSE. No, sir.

Representative VAN ZANDT. Is it perfected yet, or what is its status?

Mr. MORSE. I believe about September 15, I requested through appropriate Army channels that the Quartermaster Corps provide a new program directed toward research to run down these apparent difficulties yet unproven, so that the Army could maintain its research position in the field, with the hope that ultimately we might be in a position to proceed with large-scale production in the event this appeared economically and logistically justified. I have not yet received that program.

Representative VAN ZANDT. Do you anticipate in the near future that this program will get underway?

Mr. MORSE. Yes, sir; at a considerably reduced scale, and within the funding limitations of our fiscal year 1961 budget.

Representative VAN ZANDT. What will it represent in dollars and cents? Do you have any idea?

Mr. MORSE. I have not received the program at the moment.

Representative VAN ZANDT. Is it going to be $3 million? I thought you had something like $2 million or $3 million for fiscal 1960, did you not?

Mr. MORSE. I think the Army would find great difficulty in finding $3 million to expend in this area.

Representative VAN ZANDT. In other words, you have the money appropriated?

Mr. MORSE. No, sir; I am discussing the 1961 budget and this goes before Congress this week, I think.

Representative VAN ZANDT. How much did this study made by A. D. Little cost?

Mr. MORSE. I would defer to the Quartermaster Corps on that. I think we put a limitation of $8,000. Do you know, Mr. Beale?

General MACLAUGHLIN. I can only estimate now. We can get it for you. It was between $8,000 and $11,000.

Mr. MORSE. I think we had a limitation of $10,000.

(The information referred to follows:)

A. D. LITTLE—DA19-129-QM-733

Period July 15 to October 31, 1959.

Subject: "The Conduct of Services in Connection With the Design, Construction, and Operation of the Army Ionizing Radiation Center."

July	$2,236.12
August	5,233.76
September	2,348.82
October	1,115.18
Total	10,933.88

(The full report of Arthur D. Little, Inc., will be found in app. 3, p. 475.)

Representative VAN ZANDT. In what period of time was this study conducted?

Mr. MORSE. I had my meeting on July 15 in person with representatives of A. D. Little and I talked with them on the phone, I believe, within 2 weeks after I took office.

Representative VAN ZANDT. About the first of August they started?

Mr. MORSE. No, Mr. Van Zandt, they started before that. I initiated this by telephone and outlined the program we had in mind. The Quartermaster General cooperated immediately. They actually had unexpended funds with a contract with A. D. Little. We used those funds, which obviated the problem of getting approvals. They coordinated with the people, and talked with contractors and medical people all over the United States, mainly contractors and engineers. I received the letter on September 2, which I have already read to you which gave the conclusion.

Representative VAN ZANDT. About 5 weeks?

Mr. MORSE. Five or six weeks.

Representative VAN ZANDT. From the time you made contact with them?

Mr. MORSE. Yes, sir.

Representative VAN ZANDT. In other words, they studied and reported on a program in a period of 5 or 6 weeks which have been underway since the early 1950's.

Mr. MORSE. No, sir; they did not. They were not asked to study the program. They were asked to study the size of the plant and what I would call a business economic case study of what the cost of production would be based on the parameters we gave them. They did not get into the program. We did not ask them to. They were only concerned from an engineering economic viewpoint of what it would cost if you ran this plant in industry and tried to make some money out of it.

Mr. RAMEY. Would you say that you could conduct a comprehensive economic study for $8,000?

Mr. MORSE. On a unit of this type, you can, providing certain assumptions.

Mr. RAMEY. It would involve a more substantial sum to make a thorough study. That doesn't sound like very much effort.

Mr. MORSE. This was adequate effort for a $4 million project.

Mr. RAMEY. In terms of manpower engineeringwise, how much would that be?

Mr. MORSE. Let me explain that we gave them the Corps of Engineers estimate of construction costs. This gave them a depreciation base immediately. We had in this plant already a certain basis of production, of so many tons per day. These numbers they had. Their request was to take this kind of information and use it the way industry does to then determine the actual operating cost. We gave them an assumption that one could buy cobalt 60 at various price levels. They took $2, $1½, $1, and 50 cents. They actually gave us the operating costs at these different price values. We gave them the estimate of the cost of the equipment. They didn't get into redesigning the plant or telling us how to run it. They had all this information.

This had not been done before when I came into office on June 1. I was unable to find anyone who had made the kind of business study that you would make if you wanted to invest in a business.

Mr. RAMEY. The question is, would you want to do a little more than that, including the part that they said they left out, namely, looking at the so-called noneconomic aspects?

Mr. MORSE. No, sir. I would refer that to the Army. The only thing they left out were the military aspects of the program. This was not their job. Their job was to find out what the costs per pound to process radiated foods versus what it cost industry to freeze and distribute frozen meat. This is a simple problem that any good business organization can do or any engineer can do who has experience in the field. Bear in mind that A. D. Little had been consultant to the Quartermaster on the design of the plant. They were not cold on the subject. They were associated with the thing since 1956 in a minor way, purely from an engineering point of view and not from a medical point of view.

I also consulted with the companies that had been retained to operate the plant for the Quartermaster Corps and the contractors. I would still, if I may, like Dr. Nungester to comment further on the medical aspects of this program because he was the representative of the Army Science Panel which is a senior group of the Secretary of the Army for advice in areas of this sort.

Representative VAN ZANDT. Mr. Morse, the deeper we get into this matter the more confused I became. Back in 1956 in a prepared statement, and I quote again, the Army had this to say:

> With every indication that the pilot plant will be operating in the latter part of 1958, and economic feasibility studies in progress and will develop additional information which will be useful in determining prospective cost figures.

You had a study back in 1956.

Mr. MORSE. I have not seen it.

Representative VAN ZANDT. Of course, I realize you did not take over until June 1 of last year.

Mr. MORSE. Perhaps the representative of the Quartermaster can answer that, I cannot, sir.

General MACLAUGHLIN. We are speaking of a contract, Mr. Chairman, I didn't have any personal knowledge of it but it was with North American Aviation for an economic feasibility purpose. Maybe Dr. Siu can tell you the specifics on it.

Dr. SIU. It was a study that took about 2 years to give the first business-like logistic feasibility study of all the various possible

sources and to bracket in roughly, if you use cesium 135, this will be about the price of irradiation; if you use cobalt 60, this will be the price, fuel elements, and so forth.

Representative VAN ZANDT. Do you recall the figures of cost of that study?

Dr. SIU. I do not remember that offhand.

Representative VAN ZANDT. Would you furnish it for the record?

Dr. SIU. Yes, sir.

(The material referred to will be found in appendix 3, p. 475.)

Representative VAN ZANDT. Doctor, can you recall any other studies that have been made since the beginning of this project back in 1953?

Dr. SIU. I think we should distinguish at this point what we mean by business-like studies and what we mean by economic studies of various degrees of accuracy. There have been a number of studies as to the cost of irradiation process. As a matter of fact, most of the people in the committee are aware of the Quartermaster Corps monograph on irradiated food and there is a chapter on it in which there were many references on a study. The question comes whether or not those figures are good enough for your specific decision on the point at issue. If you want a more accurate study, for business investment, then the question comes up whether you would like to have a more specific paper study of the type even better than the Arthur D. Little study or whether you would be satisfied with the data after you get the pilot plant going.

Representative PRICE. The economic feasibility of the military you are not so much concerned with. There you are concerned with the logistic problem?

Dr. SIU. Both, sir.

Representative PRICE. The important thing in the military is logistic if you get into trouble, is that right?

Dr. SIU. That is right.

Representative PRICE. You are not going to worry about the cost if you get into trouble. It is the logistics?

Dr. SIU. That is right.

Representative PRICE. Regardless of that, you have had economic feasibility studies. We have had testimony on it before this committee.

Dr. SIU. Yes; we have had studies.

Representative PRICE. A long time ago.

Dr. SIU. Yes. The question is how accurate for your purpose.

Mr. MORSE. We are attempting here to go through with an existing plant before we have done the research or the component development. That is an expensive way to spend money for the country. I must also say, however, that this is a very difficult field. In some sense it is not as simple as the nuclear powered program for aircraft because we are dealing with human beings. You come into a question of judgment. It was my view that when we had evidence of anomalies in feeding of animals with irradiated foods in statistically significant numbers of experiments and we have had things such as blindness induced, it raised a great big red flag as far as I was concerned.

Representative PRICE. You have differences of opinion.

Mr. MORSE. We do not have differences of opinion——

Representative PRICE. Between Government agencies; the purpose of this project that we are talking about today was to try to resolve some of these differences.

Mr. MORSE. I would like to point out that these studies are the results of longer term feedings and not the short-term animal feedings.

Representative PRICE. There were exceptions taken to these things.

Mr. MORSE. Many of the studies, the results of which were coming through at the time I took office, were not known to Dr. Martin. They were not known to me when I took office, nor to my department, because the data had not all been collected. It is certainly not yet conclusive. It is because of this reason that I brought in these medical people.

Representative PRICE. Isn't the purpose of the project itself to try to help to resolve these questions? Isn't that the purpose of the center?

Mr. MORSE. No, sir.

Representative PRICE. What is it? It is a research and development center to pursue this project?

Mr. MORSE. I am differentiating between getting research data—I am directing my remarks now to the animal feeding experiments which can be done in a small scale and with existing radiation facilities that the country now has in being in AEC laboratories, university laboratories, and the industry of the country—you do not require a center of $7½ million with a capability of feeding up to 100,000 people to get animal feeding data.

I would say if the long-term animal feeding data had been completely negative, then you are correct. We would then at least not have worried about that phase of the problem and we would then have built the plant in order to get engineering and production experience so we could then go into full-scale production in industry.

Representative PRICE. That is the reason we are here. We have been trying to find out. We have been told that this installation is essential in the research and development in connection with this program. Why suddenly does it not become essential in the pursuit of the success of the program?

Mr. MORSE. It is an essential part of the program when we get farther along and are certain that the research work has been well done and we have completely eliminated any question of toxicity to humans which we can do with long-term animal feeding. This is currently the position of the Surgeon General, I believe.

Representative PRICE. We will hear testimony from different witnesses and we will have to try to reach some conclusion. It certainly seems to be quite a bit of difference of viewpoint in connection with the program.

Mr. MORSE. I still would like to have Dr. Nungester report as a medical man. Part of my decision was based on advice I had from reputable medical people. I am not competent to comment on that and I don't think many other people are either.

Representative DURHAM. Is it the plan of the Defense Department to give contracts to universities for this type of experimental work?

Mr. MORSE. Yes, sir. This is what has always been done in the past and is currently underway.

Representative DURHAM. It has been done through the AEC primarily and not through the Defense Department?

Mr. MORSE. No, sir. This has been done by the Surgeon General under the direction of the Quartermaster Corps.

Representative DURHAM. How many contracts do you have today?

Mr. MORSE. There are 30 in force at the present time. We have not terminated the research work in the universities.

Representative DURHAM. I knew you were doing it but I didn't know how extensive it was.

Mr. MORSE. Approximately 30 universities.

Representative PRICE. Dr. Nungester, are you ready to testify?

Dr. NUNGESTER. I may have forgotten what I intended to say. It is just a few words.

In going over this material on toxicity the thing that really struck my fancy as being very interesting and very important was this effect on the heart, simply because the control animals showed none of this effect whatsoever, and this disease, if you want to call it, is a very peculiar one. In the years of experience with mice I have never seen this kind of incident. I have not seen it yet. I am simply taking the word of the contractor who did the work in Chicago. So regardless of what kind of food these animals have been fed through the course of time in these various laboratories, this sort of thing does not occur. But in his experience with irradiated chickens and irradiated pork, there was about 13 percent of some 400 animals that developed this peculiar enlargement of the left auricle. This auricle enlarges to such a degree that in such cases broke and the animal suddenly bled to death. In other instances the enlarged auricle enlarged to the point where a function of the lung was not possible because of this very enlarged auricle filling most of the chest cavity.

Mr. RAMEY. It is possible to repeat these experiments?

Dr. NUNGESTER. I was just coming to that.

Yesterday I called this man in Chicago from Ann Arbor and asked about this because we were under the impression in September that he was not able to repeat it. This came partly from the fact that he changed strains of mice. He used a different strain of mice. Even there he found this lesion in some 5 out of 400 mice of the second strain, so-called A strain. Then I really hesitate to give out this data because obviously it is his and has not been published. It is fresh out of the laboratory and has not gone to press. He plans to give this at one of the national meetings in April, he said. Then he got the idea of substituting milk, irradiated or nonirradiated, for the meat. He comes out again with a high incidence, in fact almost 50 percent of the animals fed only irradiated milk developed this very peculiar lesion. When one looks at data like this you can't deny it. This is the sort of thing that is not hard to see. He didn't see it. He did not see it in the controls. Other people working with mice have not seen this thing to my knowledge. I have asked people who have worked with mice a lot and they have not seen it. So this is a rather peculiar situation. It may well be that this is limited to mice alone or maybe to even one or two strains of mice.

Maybe you will never see it in another animal and may cause no trouble whatsoever in man. There is no question that this is a possibility. But on the other hand, having seen this thing in mice and

because of the serious nature of the disease in mice, I think it calls for a great deal more work to run this thing down.

Since it is a new condition it makes it scientifically very interesting to run down and see just what is going on here. Why do these animals, fed this irradiated meat or milk, develop this kind of a peculiar lesion?

Representative PRICE. Thank you, Doctor.

Representative VAN ZANDT. Doctor, do you act as an adviser to Mr. Morse?

Dr. NUNGESTER. I acted as adviser to Mr. Morse on this situation on September 1.

Representative VAN ZANDT. Before you took your position?

Dr. NUNGESTER. I came in as a consultant and for 1 day on this.

Representative VAN ZANDT. You came in as a consultant for 1 day?

Dr. NUNGESTER. On this particular problem. I have been on the Army Scientific Advisory Board for years.

Representative VAN ZANDT. Before you advised Mr. Morse, did you confine your study of the problem to the evidence that was furnished you by the Chicago laboratory?

Dr. NUNGESTER. Our evidence was based on presentation from Colonel Hursh of the Surgeon General's Office and it was discussed around the table with representatives of the Quartermaster and others.

Representative VAN ZANDT. What I am trying to develop is, did you have any evidence from the AEC Laboratories that is involved in this program?

Dr. NUNGESTER. No, sir; I knew nothing about it.

Representative VAN ZANDT. Did you take a look at any of the evidence collected by the Quartermaster General of the Army over a period of years in connection with the feeding of animals?

Dr. NUNGESTER. I don't remember the details. That was presented at the time. I don't think there is any reason to doubt that previous work has failed to show this. I think this man in Chicago who started out to see whether or not this food was carcinogenic or not suddenly made this accidental observation. From then on he became very much interested in it.

Representative VAN ZANDT. Doctor, I have before me a statement here by Dr. Herman F. Kraybill, Princeton, N.J. and I think he is a scientist involved in this effort. He says, and I quote:

There is no evidence that there is any toxicity of irradiated foods in either man or animals. The false conclusion that there is such evidence has arisen from the misleading information published by the press relative to biological response of experimental animals fed with irradiated food.

This adds to the confusion.

Dr. NUNGESTER. Surely. We are all concerned with this. Let us take, for example, poliomylitis, when they were first having trouble making vaccine. It was assumed there was no virus in the vaccine

because this material injected in the monkeys showed it was safe. It was only after they were able to lower the resistance of the monkey with cortisone that they were able to detect small amounts of virus that still persisted in the vaccines.

Representative PRICE. I wanted to be clear on one thing. You say in a telephone message yesterday you did find that there was at least one occurrence in the experiment.

Dr. NUNGESTER. We based it primarily on the results of one experiment. That was on September 1. Since then there have been three others. One irradiation of meat, again, fed to a different strain of mice in which the incidence of this kind of disease was only 1 percent. Then a small experiment in which irradiated milk was fed to animals and three out of seven developed the lesion whereas none of the controls. Of course, seven is not very many. And then we have 18 out of some 36 developed a lesion and again none of the controls.

Representative PRICE. Mr. Ramey.

Mr. RAMEY. What kind of control did you use?

Dr. NUNGESTER. Not me.

Mr. RAMEY. I mean did the experimenter use. Did he use boiled foods?

Dr. NUNGESTER. Let me answer the boiled part first. We all used cooked meat to feed the mice. We never saw this. As far as his control is concerned, he used fresh meat that had been canned and frozen and stored in a frozen state and used that to control meat which was in cans and which had been irradiated. So this is as far as he has gone. There are more things to be done, that is obvious. That is the whole point of the thing, as I see it. Here is certainly something very different that really needs attention.

Mr. RAMEY. Do you have any other similar experiments underway with other investigators checking these results?

Dr. YOUMANS. Yes, sir.

Mr. RAMEY. For the same experiment?

Dr. YOUMANS. Yes, sir; it is being checked.

Mr. RAMEY. Have you gotten any results from them?

Dr. YOUMANS. No; it is too soon to get the results.

May I explain a little bit? The sequence of events was this: He started the studies and observed this finding. Then he tried to repeat it and was relatively unsuccessful. Then he made a second attempt to repeat it and got the findings which Dr. Nungester has just told you. Now he is going back still further for a fourth and we are adding to that studies by other people to try to confirm.

Representative PRICE. Are there any further questions? Do you have anything to add, Mr. Morse?

Mr. MORSE. No, sir; I believe not.

Representative PRICE. Thank you very much for your statement and the time you have given today.

Mr. MORSE. I hope we clarified a confused picture as best we could.

(Mr. Morse's written statement follows:)

STATEMENT OF RICHARD S. MORSE, DIRECTOR, ARMY RESEARCH AND DEVELOPMENT, TO JOINT COMMITTEE ON ATOMIC ENERGY, CONGRESS OF THE UNITED STATES, ON RADIATION STERILIZATION OF FOODS, JANUARY 14, 1960

Mr. Chairman, gentlemen of the committee, I am Richard S. Morse, Director of Army Research and Development and have been designated to represent the Army today. I have supporting witnesses whom I would like to introduce to you:

Dr. John L. Schwab, special assistant to the Director of Research and Development

Brig. Gen. W. J. Ely, Director of Army Research, Office Chief of Research and Development

Col. R. H. Oliver, Deputy Chief, Life Sciences Division, Office Chief of Research and Development

Dr. R. G. H. Siu, Technical Director, R. & E. Division, Office of the Quartermaster General

Dr. J. B. Youmans, Technical Director, Medical Research and Development Command, Office of the Surgeon General

Mr. Frank D. Beale, Jr., R. & E. Division, Office of the Quartermaster General

Dr. Walter J. Nungester, Army Scientific Advisory Panel member and director of bacteriology, University of Michigan Medical School, Ann Arbor, Mich.

My plan for the presentation is to cover very briefly the history of the program and then to answer to the best of my ability the questions which you have indicated to be of a particular interest—specifically my reasoning for the actions taken since assuming my position of Director of Research and Development on June 1, 1959.

Here is a chart (p. 3) which shows the Army's organization for research and development of irradiated foods. As you will recall the Army effort was initiated in the early 1950's. One of the earliest projects was a quartermaster research contract with Massachusetts Institute of Technology in 1951. This concerned principally the prevention of insect infestation of cereals through the use of radiation. The program continued and in 1953 the Army allocated some $672,000 for the coming year in this general area.

Effort continued and in 1954 the Army, together with the Atomic Energy Commission and the Department of Agriculture, began work on the treatment of food with ionizing radiation. The Department of Health, Education, and Welfare served in a consultant capacity through its Food and Drug Administration. The Department of Interior cooperated in the preliminary screening experiments on the effect of ionizing radiation on selected fish products.

In 1955, and again in 1956, representatives of the Army appeared before a subcommittee of your committee to testify on this program.

Since that time the program has continued. We have carried out certain short- and long-term feeding tests with animals and short-term feeding tests with humans. We have also conducted some acceptability tests. Dr. Siu is prepared to go into more detail concerning this history, if you desire. I would now like, however, to cover the developments in this program since I assumed my office on June 1 of last year.

The Army Food Irridiation Center was to have been constructed at Stockton, Calif., at an estimated cost of $7.5 million. The proposed plant was to have been of sufficient size to conduct both pilot plant and limited production scale studies on a wide variety of foods utilizing two different ionizing sources—each capable of producing completely sterilized products.

Shortly after assuming my duties as Director of Army Research and Development on June 1, 1959, I initiated a critical review of the Army's food-irradiation program, the potential economic and logistical advantages, and the possible health hazards associated with the extended use of irradiated foods by humans. I was assisted and received advice and guidance in the medical aspects of this review by the Army Scientific Advisory Panel. After additional discussions with knowledgeable people in Government and industry, I came to the conclusion that it was premature and not in the best interest of the Army or the taxpayer to proceed with construction of the proposed facility.

On September 10, 1959, I recommended to the Army Chief of Staff that all actions and plans, including further development of design drawings, specifications, and cost estimates related to constructing and equipping the Army Food

Irradiation Center, be indefinitely suspended and that action be taken to terminate most effectively and economically all contracts connected with the establishment of the center. I further requested that a revised program, oriented toward fundamental studies in the field of food irradiation, be developed.

On October 15, 1959, the Acting Chief of Staff, U.S. Army, in his memorandum to the Director of Research and Development stated that the Chief of Research and Development had completed a staff review of my recommendations of September 10, with respect to the Army's food-irradiation program. This review confirmed my conclusion that construction of the U.S. Army Irradiation Center, as presently conceived, was premature, that the program required reorientation, and that the Quartermaster General had been instructed to take appropriate action to terminate most economically all contracts for construction of the Army Food Irradiation Center and to prepare a revised research and development program.

The reasons for my decision were:

a. No available studies confirmed any substantial economic advantage to the Armed Forces through the use of irradiated foods, nor was an urgent operational requirement established. Future logistical and operational advantages did seem possible with changing concepts of warfare and advanced technology and for this reason additional research, as a part of the Armed Forces food-research program, appeared justified.

(Reference: Arthur D. Little, Inc., report to Quartermaster Radiation Planning Agency, Quartermaster R. & D. Command. Subject: "Evaluation of Size of USAIRC and Logistics of Irradiated Meat."—"In the light of current knowledge, there is no basis for choosing either frozen or irradiated meat to the exclusion of the other for military purposes; costs are about the same within the limits of accuracy of available data. The potential advantage of irradiated meat lies in the possibility of its making improved rations available to combat troops. In the case of irradiated meat, freedom from the need for refrigerated storage and transportation may have logistic implications in military planning, entirely apart from cost considerations; for example, less rigid scheduling, greater ability to alter plans on short notice, and greater flexibility in transportation may have a substantial significance that our study could not take into consideration within the time available."

b. Since there was not an urgent operational requirement which was critical for the improvement of our Armed Forces capability to wage warfare, the Army was not justified in telescoping research, development, and piloting and taking the inherent risk to push into a relatively large operation capable of full scale feeding of troops prior to the completion of the research studies.

c. My review of the possible health problems associated with the consumption of irradiated foods also, at least raised sufficient doubt to demand a critical review of the process prior to proceeding with the then-contemplated plant. In memorandum dated September 1, 1959, to the Chief of Research and Development, the Army Surgeon General stated:

"Since January 1954 an extensive research effort has been carried on in animals and humans to determine the wholesomeness and toxicity of food preserved by irradiation. Acute toxicity studies and feeding trials were completed with no obvious evidence of harmful effects.

"In preparation of long-term feeding experiments in humans, the entire program of long-term animal feeding experiments is currently under review. In this preliminary review, there are definite questions raised, some of which may have a simple and logical explanation unrelated to the irradiated food, but there is definite indication that much additional research must be conducted in order to identify the nature and cause of the changes produced by long-term feeding to animals. Certain problems which warrant further study and research are the following:

"(*a*) Lowered fertility or sterility in dogs.
"(*b*) Hemorrhagic syndromes in rats.
"(*c*) Dilatation and rupture of the left auricle in mice.
"(*d*) Blindness in rats.

"Until further clarification of these observed abnormalities can be made, extended human feeding tests and trials cannot be instituted.

"It would appear that short-term, closely controlled human feeding experiments and acceptability tests may well be warranted in view of the additional information which can be obtained.

"It is estimated that approximately 2 years of additional research effort will be required to satisfy the questions which have been raised. This is exclusive of sterility studies or of studies of ingestion of induced radioactivity with its possible long-term genetic effects. Such studies are conservatively estimated as requiring a minimum of 5 years before this food processing technique could be unequivocally approved."

On September 1 I established an advisory group of medical experts from the Army Scientific Advisory Panel to review this problem. This ad hoc group included Dr. Walter J. Nungester, professor and chairman of the Department of Bacteriology, University of Michigan, and Dr. Stanhope Bayne-Jones, Department of Health, Education, and Welfare. This ad hoc group concluded:

"Although animal feeding experiments with irradiated food were begun in 1954, it was not until about January 1959 that evidence was reported at meetings of investigators at Highland Park, Ill., indicating that irradiated foods may have toxic and pathological effects in aminals when ingested over a long period of time. These findings, which have resulted from the program of chronic toxicity studies, were reviewed for us particularily by Col. L. Hursh, Medical Corps, who has been monitoring, for the Surgeon General, the medical and health phases of the study.

"After considerable discussion it appeared to us that the data were somewhat equivocal except the dilatation and rupture of the left auricle in mice. As this lesion appeared to be statistically significant, we called Dr. Monsen, professor of anatomy at the University of Illinois, who alone among investigators had observed it. Briefly Dr. Monsen said that the dilatation and rupture of the left auricle had occurred in only the first experiment, but that in a subsequent experiment during the period of February to September 1959, it had not occurred again. He is investigating it further and has not yet reached a definite conclusion as to the relation of the feeding of irradiated food to the production of the lesion.

"Your ad hoc committee recognizes the difficulties and variables in such an extensive biological experiment as this one on the feeding of irradiated foods, and recognizes also the uncertainties in attempts to apply to human beings the results of experiments on lower animals. After listening to the presentations and discussions, we concluded that while there are indications that toxic effects may be produced by prolonged feeding of animals with irradiated foods, the results are not sufficiently definite to serve as a basis for accepting or rejecting irradiated food as a possible component of the military ration.

"We are in agreement with the position of the Surgeon General as expressed in his memorandum of September 1, 1959, paraphrased as follows:

"(*a*) Further animal experimentation should be conducted to verify and elucidate toxic pathological effects observed thus far and to search for possible additional effects.

"(*b*) Short-term, closely controlled human feeding experiments are needed and warranted to determine acceptability and nutritional values.

"(*c*) Extended feeding of irradiated foods to human beings is not warranted at present. A staged, progressive series of such tests should precede unrestricted use of this ration.

"(*d*) The research program should be continued and extended, if necessary."

It should be stressed that results on the long-term animal feeding studies are not completed and the anomalies reported to date are probably not due to irradiated food; however, since these findings have been reported it would not be possible to feed irradiated foods over long periods of time to members of the Armed Forces until these findings have been proven not to be due to irradiated food. The completion of these tests may take from 3 to 5 years. The Army plans to continue support of the basic program required to continue these studies.

There are other problems associated with the development of a satisfactory end product which must be solved before we are justified in expending large sums of funds for pilot plant production operations. These are:

1. Development of procedures for improving the taste and odor of irradiated foods.
2. The identification of chemical changes.
3. Studies on the mechanism of proteolytic enzyme reaction and procedures for controlling the proteolytic enzymatic action on meats.

4. Studies on the mechanism of destruction of microorganisms and the determination of the optimum dosage required for the destruction of resistant micro-organisms.

5. Development of suitable packaging materials and methods.

These problems as well as others must be solved prior to the initiation of large-scale operations. It is not advisable to expend large sums for pilot plant work prior to the completion of basic and applied research in this field, particularly in the light of the nominal economic and logistical advantages that appear to be inherent in the present process. This is particularly true with an entirely new and complex item as irradiated food, which must pass the most stringent safety test prior to standardization and use.

As I stated above I have directed that a revised program be developed toward the fundamental studies required to solve these and other problems.

The decision to suspend the construction of the center was released to the press at a press conference held on October 22, 1959. At this conference every effort was made to fully answer all aspects of the Army's decision. Appropriate representatives were available from the Atomic Energy Commission, the Office of the Quartermaster General, the Office of the Surgeon General, etc., and health questions were handled by qualified medical experts. It is unfortunate that a few of the press statements indicated that anomalies observed in animals had resulted from the feeding of irradiated foods, when, in fact, it was stressed at the press conference that these findings, while disturbing, were premature and inconclusive. It was specifically stated that additional long-range feeding studies, perhaps requiring from 3 to 5 years, would be required prior to approval of irradiated food as a subsistence item for the Armed Forces.

Since 1953 the Army has conducted a comprehensive program on the research and development aspects of irradiated food. These results will be of considerable value to the overall national and international program. The results of these studies, as well as all future work, will continue to be made available to all interested people here and abroad. I believe that low dose radiation for prolonging the shelf life of certain foods will have an important role in the civilian food industry within a reasonable length of time. The Army will continue to cooperate with industry and will maintain close working relationships with the Atomic Energy Commission, and other governmental agencies working on the irradiation of foods.

The Army's currently contemplated reoriented program will concentrate on high dose sterilization while the primary civilian application is low dose pasteurization of foods to extend shelf life. The problems associated with development of a satisfactory process for the complete sterilization of meats are much more complex and time consuming than those associated with low-dose pasteurization of foods required to extend the shelf life of various refrigerated foods such as seafoods, fruits, and vegetables. These two programs are complementary; however, the detail objectives and problems are considerably different.

The Army will continue to cooperate with the various governmental agencies, educational institutions, and industry on this program and will establish a procedure for close liaison with the Atomic Energy Commission in the field of irradiated food.

I am confident that, in this brief statement, I have not been able to answer many of the questions in which you have expressed an interest. I would be pleased to attempt to answer any questions which you may have and to furnish, for the record, additional information on those which I may not be able to answer to your complete satisfaction at this time.

Representative PRICE. The next witness will be a Member of Congress who desires to make a statement in connection with this hearing. The committee will now hear the Honorable John J. McFall from California.

STATEMENT OF HON. JOHN J. McFALL, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA

Representative MCFALL. Thank you, Mr. Chairman. I appreciate the opportunity to appear briefly before your committee because Sharpe Depot is of major importance to my district, the 11th Con-

gressional District of California. I understand that a careful survey was made in the summer of 1956 after your committee authorized, and Congress appropriated, funds for the consruction of this research center and it was decided that the center would be best located at Sharpe General Depot. This was partially because of the existing command and overhead facilities at Sharpe that could be utilized, and partially because Stockton is in the center of the rich agricultural San Joaquin Valley with a ready source of foods that would be processed.

The reasons for selecting Stockton in the first place are still valid today, and I trust if and when the decision is made to proceed with the plant, it will be at Sharpe General Depot. You have technical witnesses from civilian scientific ranks, the Department of the Army, and Atomic Energy Commission, to discuss the reasons behind an Army decision to defer the work on the food plant, so I will limit my testimony before you to my own experiences and that of my staff since becoming a Member of Congress in January 1957, in attempting to expedite the construction of this facility so important to my district. From the very beginning there has been an apparent reluctance from some undetermined source to proceed with the plant, but on various occasions reasons have differed as the preceding reasons were silenced.

I was told progressively, first, that private industry should help finance the plant. Then, that the production schedule was too high. Next, whether or not it was necessary was questioned. Then the source of radiation should be changed. Next that the construction should be spread out over a period of years. Then, that the Food and Drug Administration had raised questions about the program. Next, that the program had to be explained and rejustified to new officials.

And finally, last October 22, that the plan would be premature without first answering certain basic technical and economic questions. The supporting letters and memorandums from my files have been turned over to your staff in this regard.

The final reason for the suspension prior to this hearing as amplified in an October 22 press conference with Mr. Morse, which you have been discussing here today, was, it was because of "economic logistical balance." I understand there is a tape recording of this press conference which is available to you. In view of the pattern of a new question being raised as soon as the last one was satisfactorily answered, there presumably will be a new inquiry if the latest of "economic logistical balance" is satisfactorily determined.

During the entire 3-year period that this changing position was evidenced, I was repeatedly assured by the Army Quartermaster Corps that it was a matter of time. That the plant would eventually be built as an essential part of the Army plans for the future. This feeling was bolstered by the successive formal press announcements that Irradiated Products Inc., a group of the four of the largest corporations in the United States, would serve as a sort of super consultant.

Ford, Bacon & Davis, a New York engineering and architectural firm would do preliminary design work.

Varian Associates of California were awarded a $25,000 contract to design and build an electronic accelerator.

Curtiss-Wright Corp. was awarded $1.6 million to design and test and operate a cobalt 60 gamma ray facility.

The Bechtel Corp. of Oakland was awarded a $72,000 contract to design the basic plant.

Finally, on February 11, 1959, a telegram from the San Francisco division engineer to the effect that bids were being called on March 2 for actual construction of the center. This announcement was predicated "On approval of funding and final authority to advertise, subject to determination by the Office of the Secretary of Army expected during the next 2 weeks."

This call for bids was rescinded on February 27.

The above mentioned progress was reported in the following series of news releases:

March 29, 1957: Department of Defense—"Army Awards Contract for Construction of Powerful Electron Accelerator."

June 17, 1957: Department of Defense—"Commercial Production of Irradiated Food Envisioned by 1960 in Interdepartmental Report."

November 4, 1957: Department of Defense—"Production Planning Contract Awarded for Army Ionizing Center."

April 11, 1958: Department of Defense—"Plans announced for building Gamma Food Irradiator in California."

May 27, 1958: Atomic Energy Commission—"AEC Receives 15 proposals for Design and Construction of High Intensity Food Irradiator."

June 27, 1958: Atomic Energy Commission—"AEC Negotiating Contract with Curtiss-Wright for Construction of Gamma Irradiator for Army Use."

The series of contracts listed above does not in any way represent the total amount spent on the irradiation center and allied food preserving programs. You have had testimony here today in this regard, but the information which was available in my files up to the time the preparation of the statement, showed that approximately $14 million had been appropriated and spent on the food program and of this, approximately $1.6 million or more was expended on the units for the Sharp general depot plant.

In spite of this optimistic background and progress there were recurring rumors that something was amiss with the program so that I wrote to the Secretary of the Army.

On August 25, 1959, Brig. Gen. C. G. Dodge, Deputy Chief of Legislative Liaison, replied in the letter which Congressman Aspinall read previously in this hearing. In part he replied, "Progress has been substantial and encouraging and the program is now ready for the pilot plant testing phase. It is necessary that a thorough review of the program be made prior to entering this phase."

The next contact was the October 22 announcement that the program had been suspended. I have gone into some detail on this chronology because only when considered together does this pattern of reluctance that I referred to earlier become evident, in my opinion. As each reason for delay in the plant was answered, a new excuse popped up from either the Bureau of the Budget or the Department of Defense.

In my opinion, your committee should be told frankly if the decision not to proceed was a budgetary one or for reasons of economy, so you may determine for yourself the wisdom of the action. Presumably most, if not all, of the information was available earlier, yet sub-

stantial sums were expended to get the program right to the very point of construction.

If the decision not to proceed was a budgetary one you should be told so. If it is a matter of economy, it is a strange way to economize. To me personally the Army decision is all the more perplexing in the light of the Atomic Energy Commission statement by Dr. Aebersold, in the same October 22 press conference, that "The AEC work has shown that the cobalt 60 food irradiator is completely feasible," and that AEC planned to proceed with the architectural engineering work on this phase of the center.

Representative PRICE. Thank you very much, Mr. McFall.

Representative ASPINALL. Mr. Chairman, I would like to have the Congressman tell us what he thinks was meant by the statement which as I remember reads: "It was because of the economic logistical balance" that was involved. What was the meaning of that phrase?

Mr. MCFALL. You are asking for my opinion, Mr. Aspinall. I gained an opinion only by sitting and listening to witnesses this afternoon. My opinion is that economic logistical balance means that refrigerated foods are cheaper. Other than that, I cannot determine what that means. I didn't have any understanding of it at all until I came here, and I thought it was a prime example of Pentagonese which I didn't understand.

Representative ASPINALL. May your colleague from Colorado ask you further rather facetiously, do you not think this program is about researched out?

Mr. MCFALL. I would like to think so, Mr. Aspinall, because I would like to have them start building this plant in Stockton, Calif.

Thank you, Mr. Chairman.

Representative PRICE. Thank you very much, Mr. McFall.

The next witness will be Mr. John F. Floberg, member of the Atomic Energy Commission, accompanied by Dr. Aebersold and Robert E. Hollingsworth.

STATEMENT OF JOHN F. FLOBERG, COMMISSIONER, ACCOMPANIED BY DR. PAUL AEBERSOLD, DR. CHARLES SHILLING, AND ROBERT E. HOLLINGSWORTH, ATOMIC ENERGY COMMISSION

Mr. FLOBERG. Yes, Mr. Chairman, I am accompanied by strong troops. I am accompanied by Mr. Robert E. Hollingsworth, the Deputy General Manager, and Dr. Paul Aebersold, Director, Office of Isotope Development, and Dr. Charles Shilling, Deputy Director, Division of Biology and Medicine, as well as others who, I hope, answer any questions you may want to ask of the Atomic Energy Commission.

Dr. Aebersold has been the one personally most directly involved in the Atomic Energy Commission side of this program, Mr. Chairman, and if it is agreeable to you, I would ask him to be the Commission's principal witness.

Representative PRICE. Will you proceed, Dr. Aebersold.

Dr. AEBERSOLD. Mr. Chairman, gentlemen of the committee, as Commissioner Floberg said, I am Director of the Office of Isotope Development. Our Office is the one which has had the most direct liaison with the Army's food irradiation program, largely with re-

spect to irradiation facilities. I would like to introduce to you our main supporting witnesses from the Division of Biology and Medicine of the AEC, the Deputy Director, Dr. Charles Shilling, and from our Office of Isotope Development, the Deputy Director, Mr. Gene Fowler. We have also Mr. Joseph Machurek, who is Chief of our Industrial Radiation Branch, and Dr. James Liverman, Assistant Chief, Biology Branch of the Division of Biology and Medicine.

Representative VAN ZANDT. Doctor, will you state for the record how much experience you and your associates have had in this particular field of irradiating foods?

Dr. AEBERSOLD. I personally have had no experience with irradiation of food. My background is one of nuclear physics, having been an early graduate student of Dr. Earnest Lawrence 28 years ago. I worked with isotopes and many forms of radiation, neutrons, X-rays, et cetera, on all types of biological material for about 25 years. I have worked on various phases of the Atomic Energy project at Oak Ridge and Los Alamos and over the past 14 years I have been responsible for the isotope and radiation development program of the Atomic Energy Commission.

If you wish, we can enter into the record the long association of the other gentlemen with the project.

Representative PRICE. With this project?

Dr. AEBERSOLD. No, with the AEC projects.

Representative PRICE. That is the irradiation of food?

Dr. AEBERSOLD. Sir, our testimony will bring out the relationship of the AEC to the food program.

Representative PRICE. Proceed, Doctor.

Dr. AEBERSOLD. First, as you know, the Atomic Energy Commission has had an early and continuing interest in the possibilities of radiation preservation of foods. As pointed out in previous hearings before this committee, ionizing radiation gives promise of being an important large-scale application of the peaceful atom. Since the production, processing, and distribution of food is the largest industry in the world, a new development which gives promise of improvement in food availability and in the food economy would have important, worldwide consequences.

2. During early 1950, the Atomic Energy Commission began seriously to look for ways to utilize advantageously the vast amount of waste fission products accumulating from nuclear reactor operations. The potential of certain fission products, such as cesium 137, a long-life, gamma ray emitting radioisotope, looked very promising. Under the general supervision of the Atomic Energy Commission, a series of research contracts were initiated to investigate the possibilities. The contractors included the Massachusetts Institute of Technology, University of Michigan, Food Research Institute, Columbia University, American Meat Institute Foundation, Stanford Research Institute, Brookhaven National Laboratory, National Canners Association, and the Vitro Corp.

3. To stimulate interest in the field, the Commission provided kilocurie cobalt 60 gamma sources for small-scale research irradiators. The first recipients were several of the above-named institutions and the University of Chicago. The Commission has continued to produce radioisotope radiation sources and to develop gamma source

technology to meet the increasing needs for advancing irradiation technology.

4. As early as 1951 the Army Quartermaster Corps began to sponsor a small amount of research in radiation preservation of food related to specific Army needs. Army activities in this field increased rapidly over the next few years. By the time of the April 1954 hearings of your Subcommittee on Research and Development relative to the use of isotopes in agriculture, the subcommittee was informed of the impending transfer of primary responsibility to the Army Quartermaster Corps. Because of continued expressions of interest in radiation preservation of food by many members of the Joint Committee, a public hearing was held on the overall progress and potentials of the program on May 9, 1955. At that session the possibility of broadening the scope of the Army project to include civilian interests and to get it progressing as rapidly as possible was discussed.

5. In August 1955, following the Joint Committee hearing, a plan was devised to place the program on a national basis. Following approval of the plan by the Secretary of the Army and the Secretary of Defense, the broader program on radiation processed food was launched on November 22, 1955. A full review of the current state of the art and program plans was presented by Department of Defense representatives before the Atomic Energy Commission. The Defense Department expressed optimism over the eventual success of the program. The need for a more broadly based effort was brought out, with particular reference to the Commission's continued assistance in the nuclear and radiation aspects of the program. Specifically at that time the need was expressed for a very large gamma-ray source for pilot-plant scale irradiation of food and assistance requested on the design, funding, and construction of a suitable gamma-ray producing reactor.

6. The food irradiation reactor was one of the two radiation sources proposed for the planned food processing pilot plant. The reactor, 24 Mev linear accelerator and a food processing plant, constituted the main components of the U.S. Army Ionizing Radiation Center planned for Stockton, Calif.

7. The Commission agreed in December of 1955 to fill the Army request for the food irradiation reactor and place a $3 million item in its fiscal year 1957 budget for this purpose. To fund for the development of the nonnuclear portion of USAIRC, the Department of Army programed $4,500,000.

8. Prior to letting the contract for design and construction of the food irradiation reactor a full reevaluation was carried out on the desirability of proceeding with the reactor as the gamma radiation source. This reevaluation included consideration of technical difficulties being experienced due to the corrosive properties of the indium sulfate loop proposed for the reactor and the recognition that a cobalt 60 facility appeared to offer a more practical source of gamma radiation. Because of the substantial nature of the corrosion problem and the determination that a cobalt 60 irradiation facility was a cheaper and more readily available gamma radiation source, the reactor project was cancelled by the Department of Defense. In turn, the Commission was requested to design, construct, and test operate a cobalt 60 high intensity food irradiator as the gamma radiation source for the Stockton facility, using Army funds.

9. In early 1958, the Assistant Secretary of Defense for Research and Engineering provided performance specifications for the cobalt 60 facility and requested a cost estimate. Subsequently, $2,500,000 was transferred to AEC from the Army for the project. In July 1958, AEC contracted with the Curtiss-Wright Corp. for the design, construction, and test operation of the high intensity food irradiator, as the facility was called. Approximately $400,000 has been spent to date on research and development and design phases of the project. In accordance with recommendations of the Quartermaster Corps, the HIFI contract has been continued with minimal effort, including continuation of design studies.

10. Irradiation facilities at the Materials Testing Reactor, the Argonne National Laboratory, and the Commission's Savannah River plant have been the chief AEC sources utilized to date by the Department of the Army in the food programs. Additionally, the Commission has produced the radiation sources for the food irradiation work being conducted by the Department of Army at its installation at Dugway, Utah.

11. Thus the Commission's principal technical role in the national radiation preservation of food program, since this program has been administered by the Department of Army, has been the development of suitable radiation sources and irradiation facilities.

12. Shortly after the Army on October 22, 1959, announced the deferral of its radiation center, the General Manager authorized the AEC representative on the Interdepartmental Committee on Radiation Preservation of Food to suggest that the Committee formulate a national civilian program on radiation processing of food. The suggestion was adopted and an ad hoc panel was established to develop such a program and to recommend individual agency responsibilities. On January 7, 1960, the ad hoc panel made a preliminary report. This will be considered by the Interdepartmental Committee on January 26, 1960. If supported by the Committee, the program will then be referred to each member agency, including the Commission and the Department of Defense, for consideration.

(See app. 1, p. 133, for the report by the ad hoc panel of the Interdepartmental Committee on Radiation Preservation of Food and correspondence concerning the report.)

Dr. AEBERSOLD. 13. In conclusion, from the very beginning of Government support of research on radiation processed food the Commission has maintained an interest in fostering, encouraging, and developing the national program on radiation preservation of food. We continue to believe that a coordinated national program can be carried through with likelihood of success and that the domestic and international benefits would be substantial.

Representative PRICE. Doctor, the program you suggest in paragraphs 12 and 13 of this statement, if it should materialize—if the program is continued on a civilian basis, would a facility such as that suggested for Stockton be required?

Dr. AEBERSOLD. The committee has considered the civilian needs for such a facility. Inasmuch as the radiation dose required for pasteurization or substerilization treatment of food is one-tenth the dose required for the high-level sterilization, it would mean that the throughput of low-dose-treated food, would be 10 times greater. I

do not believe there would be that much need for low-dose treated food in any civilian radiation-processed-food program in the near future.

Representative PRICE. Pasteurization as against high sterilization would be sufficient in a civilian program?

Dr. AEBERSOLD. Yes, sir. A smaller facility would be able to take care of that need.

Representative PRICE. But for high sterilization you would require a facility similar to that proposed at Stockton?

Dr. AEBERSOLD. That would not be necessary in a civilian program.

Representative VAN ZANDT. Will the gentleman yield at this point? Has ground been broken for the project at Stockton?

Dr. AEBERSOLD. I don't believe it has.

General MACLAUGHLIN. Ground has not been broken, Mr. Chairman.

Representative PRICE. Mr. Floberg, does the Commission concur in the action and decision announced by the Department of Army in October 1959?

Mr. FLOBERG. We did not concur in the decision, Mr. Chairman, because we were not consulted as to the decision itself.

Representative PRICE. Did the decision take you by surprise? Did it take the Commission by surprise?

Mr. FLOBERG. The Commission was aware of the fact that the Army had this whole matter under discussion. I think it is fair to say that the actual reaching of the decision was a little bit of a surprise; yes, sir.

Representative DURHAM. About all the work that you have done in this field is that you have furnished the material and met the requirements laid down by the Quartermaster Corps for the material desired to do this job?

Mr. FLOBERG. Principally we furnished irradiation service. Now, we also furnished some assistance in the design of this facility.

Representative DURHAM. You have done no actual experimental work on food?

Mr. FLOBERG. No. This has been the Army's program. They took it over several years ago. We had done preliminary work prior to that time, but it was agreed that the Army had a direct customer interest in it. This was long before I was on the Commission. But it seems to me the decision was sensible.

Representative DURHAM. The Quartermaster Corps took it over in 1954. We began this work in 1950—or began thinking about it, at least. Do you have any contracts with universities or any private concerns in this field? or did you have any at that time?

Dr. AEBERSOLD. During the period of 1950 until the Army took over, the AEC supported projects, as I mentioned in my opening statement, institutions such as MIT, University of Columbia, University of Chicago, on more or less the fundamental aspects, the food chemistry, the changes in the food produced by radiation.

Representative DURHAM. Was any work done on animals?

Dr. AEBERSOLD. The Commission, as far as I know, did not do any toxicity studies or initiated them. Maybe Dr. Shilling can tell us.

Dr. SHILLING. I think they did not.

Representative DURHAM. With none of these institutions that you had contracts with?

Dr. AEBERSOLD. No, sir. These were purely looking at the basic fundamental problems of what happens to the food.

Representative VAN ZANDT. Doctor, is the AEC familiar with the new experimental data on mice that was mentioned here just a short period ago?

Dr. AEBERSOLD. I can say that is new information. But with respect to the biological aspects of this program, our Division of Biology and Medicine follows that more closely. I would like to refer that to Dr. Shilling.

Representative PRICE. Let us make that a general question. What significance does the Commission attach to the possible health problems associated with the consumption of irradiated food referred to by Dr. Morse in his testimony? Will you cover that subject in connection with Mr. Van Zandt's question?

Dr. SHILLING. In answer to Mr. Van Zandt's question, we heard about the additional information concerning the heart condition in the mice just today. We were familiar with the fact that there had been a report of a heart condition in one series, and the second test did not show it. We were not familiar with this other until today.

Mr. RAMEY. Are those numbers statistically significant?

Dr. SHILLING. No. I think he would agree that they have to do a great deal more work on this, and there may be other interesting explanations.

Representative PRICE. What is your reaction to the general question of the health problem raised by the statement of Mr. Morse today?

Dr. SHILLING. I think this. We have here a report of about 4 or 5 out of 30 or 40 such tests in which something was found. As a medical man, I would certainly want to check up on each one of these and rule out radiation as the cause of the difficulty before I did any massive feeding program. As was testified this morning, however, this depends on how you move ahead on one of these. If you feel you can clear up this problem as you are going ahead with the other part of the program, then you move ahead. If you feel you must clear up the problem piece by piece, then you slow it down until you have answered each question in turn. I certainly would not want to do mass feeding, however, until we had seen an answer to these questions. I think an answer can be found without too much trouble, except in the long-term sterilization part as far as the dogs are concerned. This will take time.

Representative PRICE. Mr. Floberg, I think we have already developed that the decision to defer the work on the part of the Army was not coordinated with the AEC. Dr. Aebersold made the statement that the radiation program gave good promise of being an important or having large-scale application in our peaceful atoms program. With this in mind, and a lot of us always thought of this as being part of that program, don't you think there should have been better coordination between the AEC and the Army before a decision was made to defer work?

Mr. FLOBERG. Maybe there should have been, Mr. Price. I think there has been pretty good coordination of the program itself. This last decision was a decision that was within the Army's scope of re-

sponsibility, I think. I do believe that the long-range promise along the lines that you suggest continues to be important, and I think that the Commission should continue to prosecute it for the very reasons you have suggested.

Representative PRICE. I recognize that there had been good coordination between the Army and the AEC for a long while in this program. Suddenly they are deferring this work and it does not look to me that the Army took the AEC very closely into its confidence when it came to the time of deferring the work.

Mr. FLOBERG. The deferral, we must understand, is in connection with the Stockton facility that we have been discussing here today. I don't think it is fair to say that there has been a deferral of the overall objective or anything of that sort. We are talking about whether or not the decision to build the Stockton facility was a premature decision or whether further information should have been accumulated before this particular facility was commenced. This, I think, was a very legitimate Army decision. I think they had a right to make it regardless of what the AEC thought.

Representative PRICE. Didn't the AEC have more of a right to at least participate in the delaying of the program if it desired to do so? At least it should have had a little stronger voice in the making of the decision.

Mr. FLOBERG. There is always room for improved coordination in any program, and it might be very true in this one.

Representative ASPINALL. May I ask a question, because I am not sure I understand the meaning of the statement of Dr. Aebersold?

On page 2, Doctor, in the last sentence of your paragraph 4, you make this statement:

> At that session the possibility of broadening the scope of the Army project to include civilian interests and to get it progressing as rapidly as possible was discussed.

Then you make the statement on page 5 in paragraph 12:

> Shortly after the Army on October 22, 1959, announced the deferral of its radiation center, the General Manager authorized the AEC representative on the Interdepartmental Committee on Radiation Preservation of Food to suggest that the committee formulate a national civilian program on radiation processing of food.

Did you mean to convey in those two statements that perhaps the Army went into this in the beginning with the understanding that they were willing to get into a civilian interest operation and then perhaps they have changed their position in 1959, a few years later, and they want now to get out, and that the Atomic Energy Commission is willing to throw this over to private enterprise? Is that the meaning that you have or do I read something in that that you did not intend?

Dr. AEBERSOLD. I think the Army would have to speak about the degree of the broadening of the program mentioned in paragraph 4 to include civilian interests. I perhaps could clarify the issue by indicating that the main civilian interest has been in low dose radiation treatment of food about one-tenth the dose required for sterilization. As you know, to sterilize completely, to kill the organisms in food, requires a dose of about 5 million roentgens or rad. Whereas to extend the shelf life, to kill a large fraction of the organisms that

cause spoilage, involves only a few thousand to a few hundred thousand rad.

With your permission I could read pertinent sections from a draft report on a civilian radiation processed foods program currently being prepared by the ad hoc work panel to the Interdepartmental Committee on Radiation Preservation of Food to help clarify the civilian interest in low dose substerilization treatment.

Representative ASPINALL. As I understand now, your thought in the first instance did not carry the meaning which I thought it intended to carry. Civilian interest and military interest in that situation would be the same, wouldn't it?

Dr. AEBERSOLD. Let me explain or perhaps the Army should explain. What is meant by civilian interest in the case of the Army is that there would be civilian operators of the pilot plant and private commercial firms would supply the food eventually. After this pilot plant was run for a period of time, and I think it would be run by private firms, the further production of food would be done by private industry. What we are talking about in terms of a civilian programs is one which would have food produced for civilian markets, not for the Army needs. In the Army program they are talking about civilian production of Army food. Does that help clarify the difference?

Representative ASPINALL. Let me ask the question this other way. If the Army carried it on, it would not be under the jurisdiction of the Pure Food and Drug Act, would it? But if civilian interests carried it on, it would be under the jurisdiction. Am I right or wrong?

Dr. AEBERSOLD. The Army should perhaps answer this, but it is my understanding that the Army's policy is not to feed anything to the troops that would not be cleared by the Federal Food and Drug Administration for civilian use also. Is that correct?

Dr. MORSE. That is correct.

Representative ASPINALL. I understand that there is a representative of the Pure Food and Drug Act administration present. Is that correct?

Mr. ROE. Yes, that is right.

Representative ASPINALL. Is the statement made by Dr. Aebersold correct?

Mr. ROE. I think so, although what you asked as I understood it was the Army policy and I cannot speak for them.

Representative ASPINALL. I understand that the doctor cannot speak for the Army, but the doctor put this statement in the record and I wanted to see if I understood him, that was all.

Representative PRICE. Would the gentleman from the Food and Drug Administration identify himself for the record?

Mr. ROE. Robert S. Roe, Director, Bureau of Biological and Physical Sciences, Food and Drug Administration.

Representative VAN ZANDT. Mr. Roe, have you been active or has your agency been active in working with the Quartermaster Corps as far as the consumption of irradiated food is concerned?

Mr. ROE. We have not been active in running a program of our own, but our scientists have been consulted frequently by them, and

have helped or given them advice and help in outlining the design of the animal feeding experiments.

Representative VAN ZANDT. Is it not true, Mr. Roe, that several years ago a witness from your department appeared before a subcommittee of this full committee and testified that the department had representation who sat with the Army Quartermaster Corps and offered advice that assisted the Army Quartermaster Corps in making decisions in his research and development field?

Mr. ROE. I can't say as to previous testimony, but it is true, certainly, that our scientists have been consulted by them and have worked with them in some of the design of the experiments. I think at times they have gone out to meetings to participate in the information presented.

Representative VAN ZANDT. Did your department interpose any objections to the Army Quartermaster Corps program of feeding irradiated food to some 300 officers and men at Camp Lee?

Mr. ROE. Not that I know of.

Representative VAN ZANDT. Did your department not have a representative who sat with the Army Quartermaster Corps from day to day as these programs were developed and advise them?

Mr. ROE. No, we did not sit with them from day to day. Our contract with them as far as I know was infrequent, periodic, in the form of consultations between the scientists.

Representative PRICE. Dr. Aebersold, could you state for us what type of facilities you believe would be required for the civilian program that you referred to?

Dr. AEBERSOLD. Yes, sir. May I make clear in this capacity I am not speaking for the AEC. You will note from my testimony, that the Interdepartmental Committee on Radiation Preservation of Food established an ad hoc panel to develop a program for civilian radiation processing of food. I happen to be chairman of that panel and the following remarks are made in that capacity. I must emphasize that the report in its present condition is preliminary for several reasons. One is because we did not know the complete position of the Army with respect to next year's budget and we also were not able to speak for our agencies on an official basis. Therefore any recommendation which the panel makes to the Interdepartmental Committee will have to be acted upon by the individual agencies concerned. At that time I think they can present their comments to you. The copies of the preliminary report have been furnished to the Joint Committee in my capacity as chairman of that ad hoc panel. If you wish I can give you a short summary of the preliminary report.

Representative VAN ZANDT. Doctor, is it possible that this program may revert back to the AEC?

Dr. AEBERSOLD. Commissioner Floberg would have to answer that.

Mr. FLOBERG. I suppose it will depend upon the evaluation of this Interdepartmental Committee report, Mr. Van Zandt.

Representative VAN ZANDT. The report was made available to us yesterday. We have not had a chance to analyze it yet.

Mr. FLOBERG. You are one step ahead of the Commission.

Representative VAN ZANDT. Will you read the preliminary recommendations?

Dr. AEBERSOLD. I can give you an abstract of the ad hoc panel's report. It should be mentioned that the membership consists of people from various agencies interested in the radiation preservation of food. The Atomic Energy Commission, Departments of Interior, Commerce, Small Business Administration, Quartermaster Food and Container Institute, Quartermaster Research and Engineering Command, Office of the Surgeon General, Department of Agriculture, Department of Health, Education, and Welfare, and the Federal Food and Drug Administration.

Representative PRICE. Doctor, I hope this is one committee that was trying to find a way to do something and not one of the committees that try to find a way to kill something and carry us back to the pony express.

Dr. AEBERSOLD. I assume you really desire to see definitive programs carried forward. With your permission, I would like to present a brief introduction to the panels report. There are three mechanisms of food deterioration: chemical, enzymatic and biological. The latter is due to micro-organisms and is often the prime cause of rapid deterioration. Two, radiation is effective only in retarding biological spoilage. In other words, radiation does not stop the chemical spoilage of oxidation, rancidity and other things that spoil food on a long-term basis. Also radiation does not stop the action to a significant extent of the enzymes which cause beef to spoil over a period of a few weeks when it is not frozen or cooked. Therefore, radiation will not stop some of the ordinary processes of deterioration of food.

But it is possible with rather low dose, one-tenth the sterilization dose, to kill a large fraction of the organisms that cause spoilage. This is similar to pasteurization of milk with heat. You don't go high enough in the temperature with milk to sterilize it. If you did, people probably wouldn't drink milk because it would be bad tasting. Furthermore, I am sure if you fed sterilized milk to animals, they would show up many physiological changes because it destroys a great deal of vitamins and changes the protein structure. As a matter of fact, if you realize what heat does to food, it makes a tremendous change in the food in every respect you can think of, in terms of the vitamins, amino acids, and the enzymes, color, the taste, the flavor, and the texture. So we were looking at what radiation could do which could not be done by the other agents which are used to preserve food. It turns out it can extend shelf life and keep foods in a relatively freshlike condition. They look fresh and feel fresh compared to frozen foods.

Our idea is that the civilian program would be complementary and mutually helpful to that of the Army. Our report is made on the assumption that the Army will continue at an adequate level its program on the high-dose treatment of foods.

I might say, while I can't speak for the Army, I believe about 95 percent of their effort has been in the high-dose range. They have made some studies, only a small number of studies, I believe, at the low-dose range to see what the extension of shelf life is. Under the Army conditions of food distribution, extension of shelf life would not be a very major objective. Whereas, in the civilian economy, major spoilage of food is in the first few weeks. If you don't can it or freeze it, then your spoilage sometimes occurs in a few days as with

fish and a few weeks with other items. So the extension of shelf life would be an objective in the civilian program.

As regards the current status of technology, the substerilization of marine products, chicken and fruit products to extend shelf life appears promising. Low-dose treatment also possesses commercial interest. Thus far in the Army wholesomeness studies, no untoward effects have been noted which we feel can be conclusively attributed to radiation process of food. It should be noted there have been no tests conducted as far as I know at the low-dose pasteurization levels. In this situation you would use one-tenth or less of the sterilization dose and the chance of toxicity would, I believe, be relatively reduced, giving you an increased safety factor.

Experimental evidence indicates that low energy gamma sources such as cobalt 60 and cesium 137 do not produce radioactivity in foods. Progress is being limited by the need for additional research facilities to develop the best and most economical conditions for preservation of food. This will not be available until quasi-commercial plants are built.

The ad hoc panel report on a national civilian radiation processed food program makes several recommendations. The report emphasizes the requirement to conduct more fundamental research oriented directly to the civilian processing of food. The need to conduct technical, economic, and acceptance studies aimed toward introduction of radiation process foods into the civilian economy is also identified. The immediate objective would be to concentrate on a small number of selected food products. I emphasize this because I don't think we are prepared to go forward on a broad spectrum of 56 varieties of foods. If we can pick a few foods that have good promise and carry these through to the point where we know everything we can about them, then I think we will have more chance of success.

It is suggested that the Interdepartmental Committee on Radiation Preservation of Food would provide overall guidance to this civilian program, and that the program administration, including budgeting, would be conducted by one designated agency on behalf of all the member agencies. This would not mean that the individual member agencies would not budget for their own program needs, but in order to carry out a coordinated program, particularly at the fundamental level, some one agency should be responsible. The facilities requirements include research and possibly mobile irradiators.

In addition a national radiation processed foods research and development center would materially accelerate progress. This would depend on a military need for the high level sterilized foods. As I mentioned previously, at the lower dose levels of interest in the civilian program the amount of food that is produced in a facility designed for sterilizing doses would be 10 times greater. Therefore an irradiator to process food for a civilian research program could be much smaller.

Research and development activities prepared for the civilian program would encompass food chemistry, microbiology, product development, nuclear effects, process engineering, packaging and supplementary wholesomeness studies. By the latter I mean that at low dose levels one would probably want to conduct necessary experiments to see what the margin of safety is over the higher dose levels.

Also under the civilian program we will probably be interested in different items of food. Instead of meat, poultry, ham, and so forth, which the Army is interested in, I think our major interest would be in a few varieties of fish, perhaps shrimp and several fruits at the present moment. We believe the civilian program would complement not duplicate or overlap any program continued by the Army aimed at high dose sterilization. Although there are some common problems between the low and high dose treatment of food, the investigations in general have quite different aims and an interest in different food items.

I should mention that our coordination with the Army in the past has been excellent. The Quartermaster Corps has maintained a station in our office, a liaison officer, and in the AEC we have had continuing liaison with the Quartermaster General.

The lack of coordination at the present moment was perhaps due to the chain of command between the AEC and the Army, and we have taken steps to rectify this. Dr. Morse has appointed Dr. Schwab in his own office to be in direct liaison with the AEC, and Mr. Hollingsworth, the Deputy General Manager, has appointed me to coordinate with Dr. Schwab. So if there is any lack of coordination in the future, Dr. Schwab or I will be responsible for it, as long as we remain in our present jobs, that is.

Representative DURHAM. The thing that worries me a little bit in our civilian program is the fact that your chain of command is going to be more difficult than it has been in the past, in my opinion. How are you going to determine that some canning factory is qualified technically to carry on such work as this? We always realize the difficulties in this radiation field and the application of it. Are they going to have qualified personnel? We are just fooling ourselves in the civilian idea. How broad will it be? Is it broad enough to be worth anything? You are still going to be in a position in the Commission of having to control the material and furnish the material to do this job, whether it is a canning company or whether it is a shrimp factory or whoever it happens to be that makes the application.

Dr. AEBERSOLD. It would appear that Government agencies would have to take a major lead in this for some years in the future for several reasons. One, because of the questions which have now been raised regarding wholesomeness. This means that many of the firms that have been cooperating in the program in the past may feel that they would not want to commit further funds until they were sure of the wholesomeness test. Also, when it comes to the fundamental type of research that needs to be done on microbiology, and flavor changes the mechanisms of food chemistry and so on, these firms feel they do not have enough capital to carry on a coordinated overall national program in this activity.

Representative DURHAM. The capital does not worry me as much as the technical ability of the individuals to carry out such an experiment. For example, a can of tomatoes, and whether it is low radiation or high. I would want to know.

Mr. FLOBERG. I would point out that any handling of this kind would be by a licensee of the Commission. The Commission has some five or six thousand licensees now handling radioisotopes. You are talking about the kind of licensee who would have to demonstrate his

competence to the Commission in this case before he would be licensed to handle the equipment.

Representative DURHAM. Of course, the ad hoc committee has a good deal more faith in this than the agencies involved.

Representative PRICE. Dr. Aebersold, will you read into the record and comment on paragraphs 5 and 6 of the ad hoc working group's report, pages 18 and 19?

Dr. AEBERSOLD. Of the report of the interdepartmental committee?

Representative PRICE. The committee's ad hoc working group.

Dr. AEBERSOLD. Yes, sir; the items referred to are entitled:

5. *Facilities requirements.*—In view of the combined needs of the military and civilian programs, a National Radiation Processed Foods Research and Development Center would materially accelerate progress. Attachment 1 sets forth in detail proposed facilities for radiation processed foods research and their estimated construction cost. Certain specialized radiation facilities for food processing, for example, research irradiators and mobile food irradiators, also will be necessary to achieve the foregoing program objectives.

6. *Problems foreseen.*—(*a*) Due to the budgeting cycle it would not be expected that adequate operating funds will be available for the civilian radiation processed foods program before fiscal year 1962.

(*b*) Assuming the Army arrives at a decision or other arrangements are made to proceed promptly with construction of a Research and Development Radiation Center for Food Processing, it would not be available for use before fiscal year 1962. If the center must await the customary budgeting process, it would not be available for use until fiscal year 1964. Thus 2 years can be saved if the center can be undertaken promptly.

This was predicted on the fact that there would be an Army need to test sterilized foods, because the type of facility that we were talking about would require about a million curies of cobalt and would put through a sizable amount of food. So we have alternate recommendations depending upon the action of the Department of Army in its program. May I also read the alternate statement?

Representative PRICE. Yes.

Dr. AEBERSOLD (reading):

The report of the ad hoc group contains a basic assumption that the Army program will continue as proposed by the Quartermaster Corps and will require at least partial use of the facilities comparable to the national center. Should these assumptions prove to be incorrect, it should be noted that the food throughout for the low-dose treatment will be far in excess of the near term civilian program requirements.

2. The immediate civilian requirements could be met by research and mobile irradiators.

3. The Commission presently has under construction a radiation engineering facility at Brookhaven National Laboratory which with some modification could meet the product and process development objectives envisioned for the national center relative to the civilian program including a limited amount of product irradiation foreseen. If no Army need for national center can be demonstrated, it is recommended that the center be deferred for later consideration. In addition to the mobile and research irradiators previously mentioned, it is recommended that a marine products irradiator be established as identified on page 20 of this report. In these circumstances the budget operating estimates would require reconsideration.

Representative PRICE. Does this mean without a subsequent decision of Army or AEC or both of them that this food irradiation program is pretty much at a standstill?

Dr. AEBERSOLD. Our panel recommended what should be done.

Representative PRICE. Is the Commission requesting any funds to do it?

Dr. AEBERSOLD. As stated in our testimony, this report will be reviewed by the full interdepartmental committee. It has not even been accepted by the full interdepartmental committee.

Representative PRICE. What is the status now as the result of the Army deferring its program?

Mr. FLOBERG. To the limited extent that the Commission has been participating in this up to now, there will be no change. That is not a very significant contribution to the program. As Dr. Aebersold said, the design of the facility that was under review here today is proceeding at a minimum pace. This means just enough to keep the wheels turning over.

Representative PRICE. So we are actually at a standstill.

Mr. FLOBERG. I think that overstates it, Mr. Price.

Representative PRICE. It comes pretty close to stating it accurately.

Mr. FLOBERG. No. Let me quarrel with you just a little bit here.

Representative PRICE. Let us quarrel in trying to say just where we are. Where are we?

Mr. FLOBERG. I believe that the Army has previously testified that their biological research would continue. I think this is extremely important. I think it may well——

Representative PRICE. How extensive is it? I am not quarreling with the Commission, because this thing was placed as a national program in the custody of the Army. The Army sort of let us down. Where do we stand?

Mr. FLOBERG. The food irradiation program within the Commission can be described as negligible.

Representative PRICE. That is right. It is not the Commission's fault. It was definitely agreed and a decision reached in 1955 to turn the custody over to the Army.

Mr. FLOBERG. That is right. They were the principal customer.

Representative PRICE. And the Army let us down.

Mr. FLOBERG. The Army has made a decision here with regard to this facility. They made a decision a couple of years ago with regard to the facility which has now been reversed. You understand, as Dr. Aebersold has said this has not even come to the Commission. It has not got out of the interdepartmental committee.

Representative PRICE. It has not had much time because you were caught off guard by the sudden action of the Army.

Mr. FLOBERG. Within the next few weeks or very few months, it is conceivable that the Commission will be presented with a requirement to undertake more activity in this area than it has in the past. Naturally the Commission has no position on it, because the question is only a hypothetical one at this time. I can tell you what I think the Commission's disposition will be, although this is largely in the realm of prophecy, and I hesitate to extend my reputation to that nebulous field. I do not think that the Commission's general attitude is that any program in this area must be built on a very carefully laid foundation of scientific information. I think it is awfully difficult to build a second story of the house before you have built the foundation. I believe there are a lot of elements of the foundation involved.

Representative PRICE. You have to study the recommendations that come to you from this interdepartmental committee and it will take you some time to do it. By that time it will be too late to get author-

ization in the 1961 budget, and you have to wait until 1962, so you have lost a year.

Mr. FLOBERG. The 1961 budget is out of our control for all practical purposes.

Representative PRICE. If you made the decision quickly, we might be able to take care of it before the end of the session.

Mr. FLOBERG. That is right. The 1961 budget is still in the process. It takes several months before that gestation period is terminated.

Representative PRICE. When do you think the Commission might act on the recommendation?

Mr. FLOBERG. I am back in the realm of prophecy again. It is now the middle of January. There is a lot of activity in the Commission on other programs. I would think it would be certainly spring before anything can come to the Commission.

Representative PRICE. Mr. Morse, I see you are still with us.

Mr. MORSE. I am enjoying it.

Representative PRICE. I hope the Army has not completely abandoned this program and you might be giving consideration to what the next step would be. When do you think that the Army might reach some definite decision on how they want to proceed further in the irradiation program?

Mr. MORSE. Mr. Chairman, I would like to repeat what I believe I said, perhaps this morning. Our current research work—that is, our animal feeding studies and so on—is continuing. Our expenditures in this current fiscal year are over $2 million in this area of research. We are of the opinion—I think Dr. Aebersold would agree—that we do at least have some information which we have to review, and there is a requirement for reorienting some of our long-term animal feeding studies. The Army wishes to do this. We have discussed this with the AEC. We intend to do it. When you ask me the extent to which we are going ahead on a large scale, we obviously are going to be confronted with the problem of funding. We are now awaiting in my office for the considered recommended research program from the Quartermaster General. I do not have it. I do not have access to the report which Dr. Aebersold has given your committee. I cannot comment on his approach. I think generally—he and I are in agreement—that we have a distinct difference between the sterilization and pasteurization. The former is primarily a military interest, and the latter primarily a civilian interest. The interest of the Army is in the military field and it is a more complex problem.

Representative PRICE. I believe one of your own assistants is on this ad hoc committee, and has a copy of this report.

Mr. MORSE. I am not aware of that, but this is quite possible. This is being developed jointly with the AEC. If I may point out at this time, this program also is of interest to the Department of Defense. As you are aware, Dr. York's office has shown interest in this area, and his representative, I believe special assistant to Dr. York in this particular field, concurs with the Army decision.

Representative BATES. Doctor, do I understand that this interdepartmental committee report has not been approved by the full committee?

Dr. AEBERSOLD. Yes, sir.

Representative BATES. It has not been?

Dr. AEBERSOLD. Actually it has not really been fully approved by the ad hoc panel. It was just developed in the last couple of weeks. I believe members of the panel had to hear some of the testimony here today to get a feel for what needs to be done.

Representative BATES. Who wrote the report, a staff member?

Dr. AEBERSOLD. It is being jointly developed with other member agencies. The members of the panel are listed in the front of the report. Each department representative to the panel has contributed advice and guidance within his area of competence and interest regarding program activities to be carried out. For example, in the Department of the Interior, they are concerned with fish irradiation or fish preservation. So the program with respect to experiments with fish has been developed with a representative of that agency. Likewise with the other agencies involved.

Representative BATES. All of these members here have not approved this report yet?

Dr. AEBERSOLD. That is correct. They have approved it in principle but not in detail as to the amount of facilities, irradiators, budget, et cetera. I would say part A, current status, and part B, up to the problem of facilities, has been approved.

Representative BATES. Up to the question of facility requirements?

Dr. AEBERSOLD. Yes. I think the program description, basic assumptions, program administration, and program objectives, and the types of things which were all agreed on in principle.

Representative BATES. Let us get down to facilities requirements. You have been close to this for a long time. What is your view of the Army decision with respect to Stockton?

Dr. AEBERSOLD. Under the terms of their review, I believe they were correct, because it was to meet a military need. I don't think we could properly comment on that.

Representative BATES. In addition to the military need, the other problems they brought out, the economic aspects, biological affects, and all these various things we have listened to today, in view of what you have heard plus your background, do you think the Army was sound in coming to that conclusion?

Dr. AEBERSOLD. If it was my decision, I believe I would have had a difficult time, as they have had. I may have taken a little longer and consulted with more people. I think perhaps I would finally come to the same conclusion at the present moment.

Representative VAN ZANDT. Of course, you heard this morning the letter of General Luedecke referred to several times. You most certainly concur with the position of General Luedecke; do you not?

Dr. AEBERSOLD. Yes, sir. I think there is no problem with induced radioactivity. I think from the civilian standpoint, the program still looks good. I am thinking of low dose treated foods for the civilian market. I cannot say how good it looks for military purposes. I have not been close enough to the military requirement.

Representative VAN ZANDT. I want the record to protect you.

Mr. FLOBERG. That answer might not be so inevitable in my case, Mr. Van Zandt.

Representative VAN ZANDT. I would like to ask the doctor a couple additional questions.

In the first paragraph of your statement, Doctor, you mentioned here the worldwide consequences. I immediately recalled the President's atoms-for-peace program. Do you not think that the cancellation of this program would have its effects on the President's atoms-for-peace program?

Dr. AEBERSOLD. Let me answer this by referring to an International Conference on the Preservation of Foods by Ionizing Radiation, held in July at MIT, which was attended by people from some 20 different countries of the world, expressing the interest of those countries in radiation preservation of food. I might also say that the International Atomic Energy Agency, the FOA, the Food and Agricultural Organizations, the OEEC, and various others of these European alphabets that are concerned with economic considerations in Europe, are also very much interested in radiation preservation of food at the low pasteurization levels for this reason—many European countries do not have highly developed canned and sterilized food industries. They do not have a highly developed frozen food industry. They do not have a highly developed transportation and marketing system. So to those countries radiation preservation of food at low levels could be introduced more rapidly than here and could have much more meaning. At least that is our present feeling.

I think again one would have to take a very close look at the logistics and economics for each country, because the problems are quite different for different countries. In one country it would be a matter of fish, where you have an oversupply of fish and want to market this worldwide. In another country it would be citrus fruits, et cetera.

Representative VAN ZANDT. What effect will the cancellation of this project have on our efforts in the field of medicine and agriculture and so forth?

Dr. AEBERSOLD. That is difficult to answer broadly. The program under consideration definitely has one objective, the radiation preservation of food. I don't think the other aspects of radioisotopes use is directly related, or if so only insofar as one becomes more and more concerned about radiation and its effects. The public reaction to radiation-processed foods is an area that one has to be concerned about.

Representative VAN ZANDT. That is exactly what I am trying to develop. The public now knows what happened to the rats and that this program has been canceled because of the physical defect in the rats. Is it not going to have an effect on the exposure of medicine, liquids as well as tablets, to radiation? How about exposure in the field of agriculture of seeds, and so forth?

Dr. AEBERSOLD. It does not contribute to public assurance concerning atomic energy.

Representative VAN ZANDT. What about these 30 Mennonites who acted as guinea pigs at Fitzsimons? They have eaten a lot of this food. What about the 300 officers and men at Camp Lee? What about this Joint Committee?

Dr. AEBERSOLD. I think that the Army would assure you that at the levels of food these people ate, there was no problem. I think

one must look at this in terms of the civilian program. We are not thinking of a universal processing agent. I should make it clear radiation is not comparable to heat. You cannot process everything that comes along with radiation. With heat you can process practically everything. I suppose there are some exceptions, tropical fruit, and so on. Even there canned pineapple compared to a fresh pineapple is a tremendous difference. People have gotten used to canned food and some people prefer canned pineapple to fresh pineapple.

In the case of radiation, particularly at the high sterilization levels, different items react differently. Some of them have distinct off flavors. With other food items, flavor changes are insignificant under certain situations. At the low dose substerilization levels flavor, color changes, and so forth, are much less of a problem.

I believe such things, for example, as the disinfestation of tropical fruits, that is getting fruitflies out of tropical fruit before shipment, can be done with 10,000 to 30,000 rad. This level of dose has no observable effect on the fruit, either for wholesomeness or acceptance.

Representative VAN ZANDT. I have one more question I should like to direct to Commissioner Floberg. If the Joint Committee wrote a bill prescribing a program dealing entirely with civilian use of food and the Congress approved it, do you think the AEC would take it upon themselves to set up a vigorous program?

Mr. FLOBERG. I think the AEC would conform with the law, Mr. Van Zandt. This is our intention. After all, you are asking a lawyer this question.

Representative VAN ZANDT. If you got the money.

Mr. FLOBERG. Of course, that goes without saying. I think it won't be necessary for the Joint Committee to be that specific about this program. I think we have a great interest in the program. I think that the Commission will take an objective and determined view of it when it has an opportunity to review it in the near future.

Representative VAN ZANDT. Is it not true the preliminary recommendations of the ad hoc committee give indications that this is an AEC program?

Mr. FLOBERG. Maybe the AEC should be doing more than it has been because of the civilian implications of this program which have been downgraded in the past as compared to the military implications of it. I must say, however, that I don't consider having a vigorous program to by synonymous to succumbing to the blandishments of the equipment peddlers. I think if we run a vigorous program it will be on a sound scientific basis as we know how to run it, and with development sequential and orderly.

Representative PRICE. Are there any further questions?

Representative BATES. Nucleonics indicated that if the Army is not willing to pursue a national effort, AEC should step in. Now, you have the ad hoc committee suggesting about the same. What do the witnesses have to say about that?

Mr. FLOBERG. I have not read the Nucleonics article so I don't know how to criticize it, Mr. Bates.

Representative BATES. They say they don't have a bold program.

(The article from Nucleonics magazine follows:)

[Editorial from the December 1959 issue of Nucleonics magazine]

IS THIS BOLD LEADERSHIP?

This country's leadership in the radiation preservation of food has suffered a major reversal with the Army's announcement that it has indefinitely suspended its plans to build what would have been the world's first production plant for irradiated food products—the multiton/hr Ionizing Radiation Center (USAIRC) at Sharpe General Depot, Lathrop, Calif. (Nucleonics, August 1959, p. 17).

The decision, coming as it did after 6 years of reserch and development and an investment of some $10 million, was a bitter disappointment to those in the program and to many outside who continue to look to radiation as a potentially important means for improving the military and civilian food supply—in the United States and abroad.

Was the man who made the decision—Army Research and Development Director Richard Morse—justified? The question is difficult to answer flatly and there are sincere differences of opinion.

The proposed facility, with its 24-Mev. accelerator, its 2-megacurie cobalt 60 source, and its extensive support equipment, was on tenuous ground. For one thing, a review by Morse—initiated shortly after he took his Pentagon post in June—showed that nobody had ever bothered to get a clear answer to the basic military question: Would irradiated food ease the logistics task for the military consumer? For another thing, there was widespread feeling among both Government and industry advocates for food irradiation that the USAIRC complex was ahead of its time—and that a more realistic construction program might embrace one or more small, versatile irradiators for both research and demonstration.

Despite these questionable aspects of the project, however, Morse appears to have been ill advised in reaching his decision and to have performed a great disservice in explaining it.

He discounted substantial evidence, including a report especially prepared at his request by a disinterested firm, which could have just as easily been interpreted as supporting construction of either USAIRC or an alternate facility. Although this report ordered by Morse stressed the need for conclusive data demonstrating that radiation would be logistically advantageous, there remains much to support a bold, positive conclusion that the investment in food irradiation was already large enough, and the promise of irradiation substantial enough, to justify a construction program exploiting the effort to date.

Even more distressingly, Morse, in explaining his decision, threw up a psychological roadblock which has inhibited the chances of resurrecting another construction program. This was his statement to the press that biological difficulties have shed doubt on the safety of food irradiation (Nucleonics, November 1959, p. 26).

This alleged cause for shelving USAIRC is at best halfhearted; nor was it, in any case, the crucial reason. Rather, Morse told Nucleonics, USAIRC could not be justified at this time either logistically or economically—and he decided the funds should be committed to other programs.

The biological problems—though some go as far back as 3 years—were seized upon by the lay press as startling new discoveries and twisted far out of proportion to their real importance. In the process, public confidence here and abroad has been unjustifiably and severely damaged.

For years the Army has had sole responsibility for a national food-irradiation program embracing three major goals—meeting a military need, demonstrating commercial possibilities, and assuring U.S. leadership in a field of important foreign policy consequence.

If the Army no longer is willing to pursue a national effort—in a confident and vigorous manner—it should step aside in favor of AEC.

Mr. FLOBERG. Maybe they ought to be testifying here instead of me.

Representative BATES. The interdepartmental report suggests the same, that the AEC should be the operating agency.

Mr. FLOBERG. I think we ought to take a look at that, Mr. Bates. I am not prepared to answer that question today. It would take some

thought. It would take the views of the other Commissioners before I say anything about that.

Representative BATES. When this was turned over to the Army originally in 1954, wasn't the AEC in favor of that?

Mr. FLOBERG. Yes, sir; I believe everybody concurred in that decision.

Representative BATES. Based on agreement between the AEC and the Department of Defense, the Commission terminated its report. Mr. Horner, Division of Reactor Development, made that statement. You don't know of any change in the judgment of the Commission with respect to whether it should go back into the field?

Mr. FLOBERG. No, sir; it has not come before the Commission.

Representative BATES. Doctor, from your knowledge, is there a possibility that this is a question of diet rather than anything else?

Dr. AEBERSOLD. That was our general understanding. As various things in the wholesomeness program developed, many of them in the past have been explained as a vitamin deficiency or as the result of challenging the animal. By "challenging the animal," I mean feeding 30 percent egg in the diet to dogs. This is not a normal diet for dogs. I think in some of the cases, Dr. Youmans mentioned that a very high level of spinach was fed some of the animals. When you challenge the animal that way, you have reason to believe that the challenge is the result rather than the irradiated food that was fed.

Representative BATES. At the same time do they give irradiated food and non-irradiated food? Was it that type of test?

Dr. AEBERSOLD. I am not familiar with the beginnings of this program but, as I understand it, it was considered whether a program should be conducted in which one fed a normal diet, an irradiated food diet, a cooked food diet, an irradiated cooked food diet, and then compare all of these. This would have been about twice the level of feeding. It would have been twice the cost. It was believed that in the program, as developed with the cooperation of the Federal Food and Drug Administration, most of the experiments would turn out negative, indicating that the foods fed were safe, even under diets designed to challenge the animals.

If some experiments developed in which there was an effect that might be due to the irradiated food, then it was considered that it would be cheaper to do the experiment over again under a limited program just to test that one point. I think Dr. Shilling perhaps could say this better than I.

Dr. SHILLING. You said it right.

Representative BATES. So we still have a long way to go even in terms of the tests themselves being proper.

Dr. AEBERSOLD. I don't know how the program would stand with respect to feeding pasteurized foods at one-tenth the level. It has been assumed that if clearance was obtained at the very high levels, then almost automatically, at doses at one-tenth of that, you would receive clearance. The difficulty at present is that the items of food we are most immediately interested in, due to technical and economic feasibility, are items that were not in the Army's wholesomeness program as such. The Army covered broad classes of food like fish. We are currently having a study made of the types of fish that might be

most feasible to preserve with radiation. It turns out that fish like ocean perch and halibut are the most attractive under a civilian program. These were not tested in the Army's feeding program—they are testing codfish, tuna, and shrimp, I believe—and if one takes another variety, such as ocean perch or halibut, it is not clear at the present moment whether the program as now devised by the Army would clear these related food items. This is one thing we want to clear up with the Federal Food and Drug Administration before we undertake a civilian radiation processed foods program. I think since this question of wholesomeness has been raised, you would morally and perhaps psychologically want to test the particular item that you were putting into the civilian market at the particular dose level and under the processing conditions that you would have to use. That is, the temperatures and so on, just for psychological and moral reasons, if not for legal ones.

Representative PRICE. If there are no further questions, Mr. Floberg, we certainly thank you for your testimony; and Dr. Aebersold, may I express the hope that the Commission will have all the material in from this committee and consider it, and might be able to reach a decision in time to bring it in with their authorization, or by the time we complete hearings on the authorization biil.

Mr. FLOBERG. We will certainly take your expressed wish to heart, Mr. Price.

Representative PRICE. Thank you.

The committee will stand adjourned until tomorrow morning at 10 o'clock in the same committee room.

(Thereupon, at 4:40 p.m., a recess was taken until Friday, January 15, 1960, at 10 a.m.)

NATIONAL FOOD IRRADIATION RESEARCH PROGRAM

FRIDAY, JANUARY 15, 1960

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C.

The Joint Committee met, pursuant to recess, at 10 a.m., in room P-63, the Capitol, Representative Melvin Price presiding.

Present: Representatives Price, Durham, Van Zandt, and Bates.

Also present: James T. Ramey, executive director; Richard T. Lunger, staff consultant; and Edward J. Bauser, technical adviser, Joint Committee on Atomic Energy.

Representative PRICE. The committee will be in order. This is the second day of public hearings by the Joint Committee on Atomic Energy to consider the current status of the food irradiation research program. Yesterday we received testimony from representatives of the Army and the AEC on the history, present status, and possible future plans for the program. We were unable to complete the testimony in 1 day, and we want to express our appreciation to Dr. Kraybill and Dr. Urbain who were originally scheduled to testify yesterday for staying over until today in order that the committee may have the benefit of their views. Representatives of the Army and AEC have been requested to also be present today and to be available to answer any additional questions which may come up during the hearing today.

Our first witness this morning is Dr. H. F. Kraybill, senior scientist of the Nuclear Radiation Department of Curtiss-Wright Corp. in Princeton, N.J.

We are very glad to have Dr. Kraybill with us. Doctor, if you will come around, after I add a little bit more to what I want to say before the start of this hearings, we will hear from you.

I would like to first comment, however, on the testimony that was presented yesterday. Yesterday the Director of the Army's Research and Development Staff, I might say, "sprang" an economic report to support his position in canceling or deferring the Army's irradiation project. This report had never been brought to the attention of the Joint Committee, which I think it should have been, in compliance with the Atomic Energy Act of 1954.

Similarly a medical adviser testified to some recent research results which allegedly show the deleterious effects of irradiated foods, and thereby supports the Army decision. Again this material was never brought to the prior consideration of this committee, which it should have been under provisions of the Atomic Energy Act. After all, the act provides that with respect to atomic energy matters, the Department of Defense shall keep this committee currently and fully informed.

This morning's headlines in the press around the country played up the testimony of this medical adviser. When put in proper perspective, however, probably the story will be buried somewhere in the paper, and two different points of view will not have the same public consideration.

I had our staff call the research scientist whose testimony was used by the medical adviser in his appearance before the committee yesterday. He indicated in his conversation with our staff that there was no necessary connection with irradiation as such and that he personally would eat any of the irradiated food and drink any of the irradiated milk he tested. He also indicated in his conversation with our staff that he personally thought it would be much more costly and undesirable to defer the irradiation project than to go ahead with it.

I hope that this information gets just as much press consideration as the statement of this medical adviser before the committee yesterday.

Now we are ready to hear the testimony of Dr. Kraybill.

Representative VAN ZANDT. Mr. Chairman, before Dr. Kraybill begins his statement, I would like to read into the record the background of Dr. Kraybill as taken from an article that appeared in a recent issue of the Nucleonics. I read:

> Dr. Kraybill is a recognized authority in the field of radiation and has written extensively on the subject. He has worked in the field since 1953 when he became project leader of the toxicity program of the U.S. Medical Research and Nutrition Laboratory at Denver, Colo. He was also deputy project leader of the Office of the Surgeon General, Department of Army, Washington, D.C., concerned with its national program of wholesomeness studies. He served as a consultant to the Food and Agriculture Organization of the United Nations on food radiation in Harwell, England, in November 1958. Dr. Kraybill is a senior scientist, Nuclear Radiation Department, Curtiss-Wright Corp., Princeton, N.J.

The record should contain this information before Dr. Kraybill begins to read his testimony.

TESTIMONY OF DR. HERMAN F. KRAYBILL, NUCLEAR RADIATION DEPARTMENT, CURTISS-WRIGHT CORP., PRINCETON, N.J.

Dr. KRAYBILL. Mr. Chairman, members of the committee, the concern which was expressed in the press recently relative to the biological response of experimental animals fed irradiated foods was alleviated to a degree by a detailed discussion which appeared in Nucleonics, the article entitled, "Are Irradiated Foods Harmful" (H. F. Kraybill, Nucleonics 18, 112–117, January 1960). This document should be an exhibit in this statement and is a point of reference.

Representative BATES. Mr. Chairman, I ask unanimous consent that the statement be inserted in the record at this point.

Representative PRICE. Without objection, it is so ordered.

(The information referred to follows:)

[Reprinted from Nucleonics, January 1960, vol. 18, No. 1]

ARE IRRADIATED FOODS HARMFUL?

(By Herman F. Kraybill, Princeton, N.J.)

BEHIND THE STORY

The Army program on irradiated foods suffered a setback in October when Richard Morse, Army Chief of Research and Development, announced at a press conference that program promise did not match cost (NU, November 1959, p. 26). Objections have been raised that Morse did food irradiation a disservice in his explanation by exaggerating biological problems and leading the nontechnical press to false conclusions (NU, December 1959, p. 17). The author, a recognized authority on wholesomeness of irradiated foods, tells why he feels that published conclusions are not warranted by the available evidence. —*Editors*

There is no evidence that there is any toxicity in irradiated foods for either man or animals. The false conclusion that there is such evidence has arisen from misleading information published by the press relative to biological response of experimental animals fed with irradiated foods.

ON THE RECORD

Since the inauguration of the Army program on radiation preservation of foods, annual reports to Congress have consistently stated that when irradiated foods are fed to experimental animals or man, there is no observed toxicity (1). Earlier this year a summary report presented by the Office of the Surgeon General restated that there was no direct evidence of any nutritional or pathological toxic phenomena prevailing when irradiated foods are consumed by animals or man (2).

More recently representatives of the Office of the Surgeon General stated that no ill effects on growth, reproduction, and longevity could be traced to irradiated food (3, 4). There are many publications in the scientific literature that document the fact that thus far no toxicity has been observed (5, 6).

On the other hand, recent newspaper stories connote to the unwary that indeed irradiated foods fed to animals have given rise to (*a*) bleeding disorders in rats (hemorrhagic diathesis), (*b*) blindness in rats, (*c*) heart defect or auricular rupture in mice, and (*d*) sterility or infertility in dogs.

Experimental findings related to these effects but by no means connoting such conclusions have been available in reports for some time (7). Knowledge of all this prevailed when official reports indicated that no toxicity was evident in the ingestion of irradiated foods.

BLEEDING IN RATS

As early as 1955 it was observed that feeding a specific irradiated diet produced an increased blood-clotting time in chicks (8). Although ionizing radiation had some destructive effect on vitamin K (antihemorrhagic factor), the addition of high-vitamin-K components such as alfalfa or spinach prevented the alteration in clotting time.

Others observed a hemorrhagic diathesis in rats fed irradiated beef (35 percent solids) in combination with a nutritionally adequate synthetic ration (9). The syndrome was more predominant in male rats. The diet was not supplemented with menadione (vitamin K) since it has been generally believed that the rat is capable of synthesizing vitamin K in the gastrointestinal tract. More recently several investigators have shown that the mere addition of soybean protein to a synthetic ration will induce bleeding in rats (10).

Occurrence of bleeding can be attributed to either destruction of vitamin K or failure to synthesize the vitamin by the animal under certain conditions. The exact mechanism is not fully understood at the present time. However, the administration of vitamin K will correct the condition. It was first thought that oxidized or degradative products formed in the irradiation of beef caused the destruction of vitamin K (5). However, it has since been shown that under similar conditions the feeding of cooked meat or pork at 35 percent solids level

in diet, along with synthetic ration will also induce the hemorrhagic diathesis (5). Heated or oxidized fats have similar effects (2). For some time therefore the effect has been ascribed to an artifact in the diet. It is doubtful that these findings have any parallel in human nutrition.

This phenomenon is important in our understanding of vitamin K metabolism and demonstrates that radiation or heat processing can produce nutritional deficiencies. But this has not toxicological significance.

When a diet is not supplemented with vitamin K, a synthetic ration to which cooked meats, heated fats or even soybean protein are added can induce hemorrhage. Addition of vitamin K or a diet containing a wide spectrum of vitamin-K-containing foods will prevent the hemorrhagic syndrome. Thus the observed effects are definitely nutritional and there is no toxicological effect that can be ascribed to the feeding of irradiated beef.

CONGENITAL BLINDNESS

Richardson and his colleagues noted in 1955 that with a particular strain of rats offspring were born blind when either an irradiated or nonirradiated ration was fed to experimental animals (10). It was first observed that the incidence of congenital blindness was slightly higher in offspring from mothers receiving the irradiated diet. However, in repeat experiments it was observed that congenital blindness in offspring was slightly less from mothers receiving an irradiated synthetic diet than from those receiving the nonirradiated control diet.

Therefore, it appears that the incidence of blindness is not associated with irradiation of the food. The incidence of blindness has been low in every case, and blindness has been observed in other completely unrelated experimental work using this strain of rats.

The data from these studies establishes that the irradiated foods are equal in nutritive value to nonirradiated foods and that they are not toxic.

STERILITY IN DOGS

In 1958 McCay observed that some female beagles failed to conceive in a group that was fed 35 percent solids of irradiated beef (11). Similarly a few dogs fed irradiated egg solids had been noted previously by other investigators to exhibit this same phenomenon (12). These findings have not been consistent since previous experiments and subsequent feeding trials with dogs fed irradiated meats or eggs have failed to produce infertility (7, 11).

Seven other investigators feeding a wide selection of foods, irradiated and nonirradiated, to approximately 100 dogs have failed to confirm these unique findings thus far (7). Considerable attention has been given to the administration of fat-soluble vitamins, particularly vitamins A, E and K when irradiated foods are tested. In the beef-feeding experiments the fat-soluble vitamin supplement was given only once a month to the dogs. It is probable that significant vitamin E destruction—repeatedly demonstrated in rats—may play a significant role in these few cases of reproductive failure. Partial correction of the reproductive failure in dogs fed irradiated dried whole eggs has been brought about by supplementing the diet with biotin, again suggesting a vitamin-deficiency relationship (12).

Nutritional and genetic parameters doubtless have some bearing on these observations. None of the investigators have ascribed these effects to the general feeding of irradiated foods because these results are not consistently noted and reproducible. Neither has the causative agent, if in truth there is one, been ascribed to a toxicity resulting from feeding irradiated foods. Finally, the translation of these results to human nutrition on the basis of a possible vitamin E deficiency cannot be made since the role of this vitamin in human physiology has not been established.

HEART DEFECT

In 1958 Monsen made the interesting observation that some mice on an irradiated ration developed a rupture of the auricle (13). This finding seemed to be quite accidental in that this lesion was produced predominantly for 3 months in the fall of 1958 and after that time the auricular rupture could not be duplicated in any strain of mice whether they were fed irradiated or nonirradiated foods. Neither could the omissiion or supplementation of vitamins to any diet or varying the composition of the diet shed any light as to the possibility of a

causative agent in this situation. If toxic factors are present in foods it should be possible to demonstrate them in repeat experiments, analogous in design.

It is impossible to point with certainty to the presence of all important vitamins in the diet during the three-month period. A vitamin antagonist may have been present or a toxic factor may have prevailed in the basic components of the commercial synthetic ration. It is quite evident, however, that no toxicological property can be associated or related to the feeding of irradiated foods. In addition such observations have not been confirmed in the feeding of a broad spectrum of irradiated foods to hundreds of mice in the work reported by other investigators.

BIBLIOGRAPHY

1. Annual Reports, Department of the Army (1954) (1955); hearings before the Subcommittee on Research and Development of the Joint Committee on Atomic Energy, Congress of the U.S., on "Radiation Sterilization of Foods."
2. Summary Report presented by the Office of the Surgeon General, Department of the Army, at the Contractors' 6th Annual Meeting (Quartermaster Corps) on Radiation Preservation of Foods Project (Highland Park, Ill., Jan. 26–28, 1959).
3. I. C. Plough. A program for the evaluation of the possible toxicity of irradiated foods, paper presented at the International Symposium on the Radiation Preservation of Foods (Cambridge, Mass., July 27–30, 1959).
4. M. S. Read. The effects of ionizing radiations on the nutritive value of foods, paper presented at the International Symposium on the Radiation Preservation of Foods (Cambridge, Mass., July 27–30, 1959).
5. H. F. Kraybill. Safety in the operation of radiation sources and use of irradiated foods, *Intern. J. Appl. Radiation Isotopes* 6, 233 (1959).
6. H. F. Kraybill. Current status of applications in the pasteurization or sterilization of foods by ionizing radiation, Proceedings of the Second Annual Texas Conference on the Utilization of Atomic Energy (Texas Agricultural and Mechanical College, College Station, Nov. 12–13, 1959).
7. M. S. Read. Résumé of significant findings by surgeon general's contractors on program—wholesomeness of gamma irradiated foods: March 15 to September 15, 1959, U.S. Medical Research and Nutrition Laboratory Report (Denver, Colo., November 1959).
8. L. R. Richardson, P. Woodworth, S. Coleman. Effect of ionizing radiations on vitamin K, *Federation Proc.* 15, 924 (1956).
9. V. C. Metta, M. S. Mameesh, B. C. Johnson. Vitamin K deficiency in rats induced by feeding of irradiated beef, *J. Nutrition* 69, 18 (1959).
10. L. R. Richardson. A long range investigation of the nutrition properties of irradiated foods, Progress Report 14 to the Office of the Surgeon General, Dept. of the Army (Texas Agricultural and Mechanical College, College Station, September 1959).
11. C. M. McCay, private communication to H. F. Kraybill on reproduction studies with dogs (July 31, 1959).
12. S. Miller, B. E. Proctor. Breeding studies on dogs receiving irradiated dried whole eggs, Report to Department of the Army (Massachusetts Institute of Technology, Cambridge, Mass., September 1959).
13. H. Monsen. Possible carcinogenicity of irradiated foods, Progress Report to the Office of the Surgeon General, Department of Army (University of Illinois, Urbana, Oct. 15, 1959).

Dr. KRAYBILL. However, further facts are now available in support of these comments.

Both potential toxicity and nutritional adequacy are components in gross physiological response of a test animal to the challenge of a test food. In some cases they may be difficult to separate experimentally. For this reason, inadvertently an observed biological response could be characterized as toxicity effect when in truth a nutritional imbalance in the diet produced the certain phenomena. Such may have been the case in the interpretation of the findings reported on the four biological responses referred to in the above article.

Representative VAN ZANDT. Doctor, at this point would you just elaborate on that statement and go into a little more detail.

Dr. KRAYBILL. Yes. In the wholesomeness studies originally set up by the Office of Surgeon General, there were certain criteria which we had to check on for a test animal when a test food was given and such criteria that we used were the effect on growth, reproduction, lactational performance, and whether the food indeed induced any spontaneous tumor formation.

When you feed a test food to an animal, you are going to get a biological response that may be due, first, to a toxic component in the food. Let us say in the irradiation process, you may irradiate carbohydrates, proteins and fats, and produce end products that could be toxic. This is what we set out to prove, whether there was any toxicity because of these compounds.

The other factor, as I just indicated, is nutritional adequacy. We attempt in all cases to provide the animal with a nutritionally adequate diet so that we are only testing for toxicity per se. This is the idea. This is the goal. But we have found by experience in these tests that feeding an animal in some cases 35-percent solids of a certain food may produce, as I indicated here, a nutritional imbalance.

I will give you an example of this. Back in 1954, we set out to test irradiated spinach to determine its toxicity. After 30 days we noted some physiological aberrations in these rats. We did not know what the trouble was. We should have gone back and checked and found that spinach has a very high content of oxalic acid. If you feed 35 percent solids of spinach in a diet—this amounts to 580 grams of wet spinach and about 60 grams of dry ration—the spinach provides a tremendous proportion of the diet, and the amount of oxalic acid in the spinach hooked up with the calcium in the blood to deplete the animal of calcium.

We repeated these experiments and added calcium to the diet, and we had no further difficulties. Here is a case in point where misinterpretation of the results at that time would have led us to believe that irradiated spinach or irradiated food was in truth causing the trouble when it was not really; it was oxalic acid.

Representative VAN ZANDT. In other words, Doctor, you are actually challenging the findings of a previous witness.

Dr. KRAYBILL. I am more or less challenging the implication that they left here. It is very dangerous to leave the implication that there is a toxicity. The word "toxicity" has negative connotation.

Back in 1954, we preferred not to use that word. As you know, this part of the program has been entitled "Wholesomeness Studies." Toxicity has a negative sound and it means just what it says. You have a toxic compound. But a wholesomeness study involves, as I indicated a while ago, both parameters, nutritional inadequacy and toxicity.

I would like to make that fine line of distinction because in truth a nutritional inadequacy we can correct. We know what causes it. As I will show later in my statement, heat-processed foods will produce similar effects as we reported here for irradiated foods.

Representative BATES. Do I understand, then, that if this test was conducted with nonirradiated foods, it would perhaps have had identical results?

Dr. KRAYBILL. I would like to go back and say here when we had the original experimental design for these experiments, we conferred with the Food and Drug Administration, and at that time they recom-

mended that we put into the design a group of rats that consumed heat-processed foods. When I say heat processed, I don't mean cooked. I mean canned foods that have been heated to high temperatures. If we had done that and would have had that data available today, I think we would have shown many analogous situations between feeding heat-processed foods at a level of 35-percent solids in the diet to the same sort of thing that we have observed in the case of feeding irradiated foods.

Representative BATES. The answer to the question is "Yes"?

Dr. KRAYBILL. Yes. The requirement that an arbitrary level of 35-percent solids of the test food be fed has in itself introduced feeding problems and through experience the investigator has discovered that this type of diet may produce a nutritional imbalance. Rigorous adherence to this requirement can produce biological aberrations which in the case of egg solids and coleslaw fed to dogs were quickly corrected.

I would like to state that Dr. Miller at MIT found that he had to reduce the level of egg solids fed back to 20 percent. We don't know yet if this level of egg solids in the diet may in truth be too high. On the coleslaw that is referred to here, Dr. Hale, at Georgia Coastal Plains Experimental Station, found that he simply could not feed 35 percent of solids of coleslaw because the daily requirement here for the dog was just too high. Coleslaw has a tremendous amount of water, 92-percent water, and the dog simply does not have a large enough stomach to handle this large amount of food. So we had to cut the level of coleslaw back to 20 percent.

Representative BATES. A high degree of egg solids would give you high cholesterol anyway.

Dr. KRAYBILL. Yes. I don't think that is so much involved here. I think with the egg solids feeding we are concerned with a material, avidin, which is an antagonist to one important vitamin, which is biotin.

Representative BATES. I am talking about the effect of one particular food. Even if it is not irradiated, it has an effect upon the blood system.

Dr. KRAYBILL. Yes. There are certain antagonistic effects you get due to certain components in the food per se that has nothing at all to do with the processing of the food, and this should be recognized.

Representative VAN ZANDT. Doctor, in your opening paragraph you say the concern which was expressed in the press recently relative to the biological response of experimental animals fed irradiated foods. Would you say that the implication that has been contained in the press and taken from statements of certain individuals, and also contained in statements here yesterday, where the term "toxicity" was used, has really damaged the program to some extent?

Dr. KRAYBILL. I would like to make a statement right to that point. The biological responses of test animals fed irradiated foods referred to in this hearing are not new findings. No toxicological significance was ascribed to these observations previously. The blindness in the rats and the bleeding of rats have definitely no relationship to feeding irradiated foods per se, and they should not have been included. Recent report by Dr. Richardson establishes the fact, his report was issued in September 1959, that the blindness observed in rats fed

irradiated or nonirradiated foods is a genetic factor and such animals have been found in his colony on other experiments conducted over quite a few years. Dr. Richardson's observations came out in 1955.

The bleeding syndrome can be produced by cooked pork. It can also be produced by soybean protein, not processed at all, and other foods. The bleeding phenomenon is corrected by adding vitamin K to the diet. The rat obtains most of his vitamin K by consuming his own excrement. When he consumes irradiated meats, he recycles very little of his feces, consequently a vitamin K deficiency. The bleeding syndrome we had knowledge of back about 2 or 3 years ago. As I indicated, the blindness effect we noted back in 1955. The implication left that irradiated foods are toxic is not scientifically warranted, and such implications are indeed quite damaging. Such a concept is not shared by any of the five investigators who conducted the work. Those I could cite. Dr. Monsen at the University of Illinois. Dr. Miller and his group at MIT. Dr. McCay at Cornell. Dr. B. Connor Johnson at the University of Illinois. Dr. Richardson at Texas A. & M.

Representative BATES. Doctor, are you saying that the conclusions given to us yesterday are wrong, or that they might be wrong?

Dr. KRAYBILL. They are partially incorrect, as I stated earlier, in that they leave an implication that there is a true toxicity effect here. I would like to speak to the point that in some of these cases they are nutritional inadequacies, and we are not too much disturbed about the nutritional inadequacy. Back in the days when I was in the Surgeon General's program, we had knowledge of these effects, and we refrained from making comment on them, because we knew that they were nutritional problems, and they could be cleared up.

Representative BATES. Are you saying that this could not be caused by irradiation?

Dr. KRAYBILL. Irradiation will have a damaging effect, as I would like to comment here, on the vitamins. This will produce an effect. But so will heat-process foods also. I think we should remember that. If we add the vitamin we can correct it. (Vitamin deficiencies can be corrected by fortification of diet with vitamins. This is a common practice in the food industry.) Like in the bleeding syndrome, as I indicated, when we added vitamin K back to the diet, we prevented the bleeding.

Representative VAN ZANDT. Doctor, a moment ago you mentioned the names of very prominent scientists. Is it true that these gentlemen have been involved in this program for many years?

Dr. KRAYBILL. These men that I have mentioned have been in the program: Dr. Richardson came on the scene in 1954; Dr. Monsen about 2 years ago; Dr. Miller and the late Dr. Proctor have been in this program for many years; Dr. Johnson has been in the program since 1954; Dr. McCay was in the program since 1954. I would like to add here that these men are eminent biochemists and outstanding nutritionists.

Representative PRICE. Is Dr. Monsen the scientist to whom the medical adviser yesterday was referring?

Dr. KRAYBILL. He is the man who did the work on the heart defect.

Representative PRICE. Is it your view that the interpretations of his findings that were discussed here yesterday were not exactly cor-

rect in the implications they left by the manner in which they were presented yesterday?

Dr. KRAYBILL. I think your statement at the opening of this meeting was quite significant, because it confirms a previous conversation which I had with Dr. Monsen by telephone.

Representative PRICE. What did Dr. Monsen tell you?

Dr. KRAYBILL. Dr. Monsen told me that he felt that this finding he had, had in truth not much toxicological significance. He suspected that it may have some nutritional importance.

Representative PRICE. This is what he told our staff yesterday.

Dr. KRAYBILL. This is what he told me. The five investigators that I have named here have read the article I wrote in Nucleonics, and they saw it before it was published, and they concurred 100 percent with the comments that I have made in that article.

Representative VAN ZANDT. In other words, based on your statement, this group of scientists represent about 10 to 12 years of effort. One physicist had 4 years and another had 2, and so forth.

Dr. KRAYBILL. Yes.

Representative VAN ZANDT. Not a single one of them would disagree with your statement?

Dr. KRAYBILL. No; they will not. As a matter of fact, they will go so far to say that my statements are too conservative.

Representative PRICE. It is a little difficult for me to put this in perspective, and I would not want to involve you in any political controversy with the Department of the Army, but in the light of what Dr. Monsen told you and told our staff just this morning, it is a little hard for me to see how the medical adviser to the Army would leave the implication that he did before the committee.

Dr. KRAYBILL. All three of these situations, I think, are pretty well cut and dried. The hemorrhagic diathesis as I pointed out is certainly no problem. The blindness in rats can be dismissed. As to the sterility in dogs, I think, we found that biotin will partially correct this situation, and also that the dogs used at Cornell and MIT were the same strain, and no one else has produced this. Here is a very significant thing in the toxicity program. If these findings are real, then others should be able to duplicate them. When we ran into this hemorrhagic syndrome in 1956, we were not sure that this was a real finding. So we duplicated in our laboratories in Denver the same type of experiment, and we were able to produce it. Since then there have been four or five other investigators working on the same project, and they have produced this vitamin K destruction syndrome also.

Representative VAN ZANDT. Doctor, when you were employed by the Army in this program, did you have the conviction the Army had a very definite need for this type of food?

Dr. KRAYBILL. I had a conviction at that time that radiation processing may have applications in some areas. I cannot say that it is going to be a panacea. I think in the earlier years of the program everybody thought that frozen foods were going to be dispensed with and that all canned foods could be eliminated.

Representative VAN ZANDT. Later on when you shifted over to the Surgeon General, what was your thinking, then, as far as the value of the program was concerned?

Dr. KRAYBILL. I was wholeheartedly in support of it, because I saw many useful areas of application of irradiation processing.

Representative BATES. Doctor, if men in combat had a steady diet of nothing but irradiated food, would that be dangerous insofar as an unbalanced meal?

Dr. KRAYBILL. That is a pretty tough question to ask. Preliminary experiments with rats on a complete diet of a mixed spectrum of irradiated foods would indicate no adverse effects. Let me frame this in another way . If you gave a man C ration for a very long period of time, we don't know what adverse effects this would have. Some people suspect there may be an adverse effect. Anybody who has been in the military will say if you try to feed me C rations more than 6 weeks, I won't take it. The important aspect about your diet is that you eat only a fraction of processed foods and you do eat fresh vegetables. This is important because you get certain essential nutrients from these fresh unprocessed foods that are quite important.

Representative BATES. I understand that, and that is the reason I asked about combat where you don't get fresh foods.

Dr. KRAYBILL. Your question is important because in these experiments that Dr. Monsen conducted and some of the rest of the people, they are feeding a diet of 100 percent irradiated foods for 2 years. That is a very severe challenge. This is completely processed foods.

Representative VAN ZANDT. Doctor, you were identified with the government at Denver. Did this not place you in close relationship to the program that involved the Mennonites at the Fitzsimons Army Hospital?

Dr. KRAYBILL. Yes, it did. I was the project leader.

Representative VAN ZANDT. Did you find any ill effects of the participating Mennonites from the irradiated food that they ate?

Dr. KRAYBILL. No, we did not. Colonel Plough who is the Commandant of that lab reported this summer at the International Symposium on Reservation Preservation of Foods at Cambridge, Mass., and that there was no toxicity.

I would like to make a statement on that point.

Representative PRICE. How long did these tests last?

Dr. KRAYBILL. These subjects were fed irradiated foods 15 days. It is not a long period of time.

Representative VAN ZANDT. After they left the hospital they were called back periodically?

Dr. KRAYBILL. They were called back every 6 months and examined clinically. Human feeding experiments on 23 irradiated foods stored at ambient temperature and fed for 15-day periods have demonstrated that these foods are not toxic to man. That is briefly the report of the test at Fitzsimons Army Hospital.

Representative VAN ZANDT. Let me continue the line of questioning involving the consumption of irradiated food by humans. What about the 300 officers and men at Camp Lee? Are you familiar with that program?

Dr. KRAYBILL. No, I was not. The Office of Surgeon General, in Washington, D.C., and the people of the Office of the Quartermaster General, conducetd that study. I am not too familiar with that study.

I would like to continue again on my comments.

Processing foods by irradiation causes some destruction of vitamins. Heat processing causes a greater destruction. However, canned foods are widely accepted. Were the experiments so designed to test heat processed foods at the high level of 35 percent solids in the diet undoubtedly adverse biological responses would be noted as the result of the nutritional deficiencies. This statement is well confirmed in feeding experiments in which heat-processed pork fed at a level of 35 percent solids in a diet to rats produced the vitamin K deficiency or hemorrhagic syndrome.

I am sure we are not going to stop eating cooked pork after today.

It can also be deduced from this latter statement that nonirradiated beef or for that matter irradiated beef is a poor source of vitamin K.

Vitamin K added to a diet of nonirradiated beef is destroyed on contact just as is the vitamin in K that has contact with irradiated beef. Interestingly enough, the omission of vitamins A and E from a diet containing irradiated beef will bring about almost the complete disappearance of the bleeding symptoms observed in rats. The vitamin relationship and the dependence of vitamins in this phenomena fairly well establishes that nutritional parameters are involved and there is no toxicity effect. Addition of vitamin K to the diet corrects the deficiency. Since it is known that vitamin K destruction in vegetables is slight, one might deduce that a mixed diet of vegetables and meat such as consumed by man in his dietary pattern would not elicit the hemorrhagic diathesis. Such is the case, since such a diet fed to rats was incapable of producing the bleeding phenomena.

Dr. Richardson stated in a publication almost 4 years ago where he irradiated spinach and alfalfa that with certain vegetables you could not produce a vitamin K deficiency, and since most people eat such a diet, you would perhaps never be able to produce this bleeding syndrome in man.

With respect to the dog-feeding experiments at Cornell University and Massachusetts Institute of Technology, wherein pork, beef, and egg solids were fed and reproductive failures noted, it is important to note that animals of like strain were used and the investigator at MIT believes that genetic aberrations might play a significant role. The possibility of a vitamin E deficiency in the meat fed animals and the importance of the biotin and avidin antagonism in feeding egg solids however, focuses attention on the nutritional factors in this situation.

Thus far 13 irradiated foods have been successfully fed to dogs for a 2-year period with no toxic manifestations. This is the 2-year period that is required by the Food and Drug Administration. The histopathology has not been completed on these animals.

From a group of 22 irradiated foods, 10 foods have also been fed to rats to date with no untoward effects. After 2 years of extensive testing irradiated bacon (treated at a radiation dose of 5.58 megarads) has not demonstrated any carcinogenic properties. Human feeding experiments on 23 irradiated foods stored at ambient temperatures the foods fed for 15 day periods have demonstrated that these foods are not toxic to man.

Representatives BATES. All of this was on a balanced basis. It was not 35 percent solids.

Dr. KRAYBILL. No. These experiments have all been conducted with 35 percent solids except in those cases like egg solids and coleslaw where we had to decrease to 20. In testing some products, you may not run into this nutritional imbalance. If you were testing meat at 35 percent solids, you will find that meat is a very good source of most all nutrients. But when you are testing with 35 percent solids of something like a vegetable, even in spite of the fact that you think you have added all the known vitamins and supplements, you may run into trouble. I would like to point out there, too, that in these experiments there is such a thing as a technician failure. This happens in the best of families. Some vitamin can be left out of the diet. It is very dangerous to attach much validity to results from a preliminary experiment, because in truth, when you repeat it, you find you may have left out one of these important vitamins.

This happened in one laboratory where they left out thiamine, and in 30 days they got in trouble. In checking back, the laboratory technician said, "I left out thiamine," and the investigator immediately said, "That is the source of our trouble."

Another thing I would like to indicate here is that in the early days of these experiments, we would note one effect with the first generation of rats. (In the 2-year experiment with rats, you usually work with four generations.) In the progress reports that are issued by an investigator, he will indicate something like this:

In the first generation study, I noticed that there was a difference in the reproductive performance of females in the irradiated food group as compared with the controls. He would be inclined to say that this is statistically significant. Therefore, radiation processing of the food has some effect insofar as reproduction is concerned. When he gets to the second generation he finds a reverse effect. When he gets to the third generation he may duplicate the finding on the first generation. When he gets to the fourth, he may find the same effect in the fourth generation that he got in the second generation. Therefore, we feel that you should be very conservative in making any statements on these feeding experiments with an animal until you have all your evidence and all your data completely summarized.

I think some of these statements made in the press on the biological response that we have gotten from these animals has been extremely embarrassing to the five investigators that I have mentioned, because they have not had a chance to determine completely whether there might be a nutritional inadequacy here and whether some vitamin may in truth have been left out of the diet.

I will tell you what can happen on vitamin E. Back in 1948 we found out that there is a very destructive effect on vitamin E. If you did not give vitamin E to the rat orally, preceding the administration of a diet you would run into reproductive troubles. We learned this technique back in 1953, that we had to give vitamin E separately to these animals. From this experience, we know now that this is a very important technique to observe.

Representative DURHAM. Doctor, on the genetic effects in the rats, for many, many years have been all kinds of experiments done on rats, feeding and everything else. Would this cycle apply normally without irradiated foods? I mean the law productive rate one year and a high productive rate next year, and so on?

Dr. KRAYBILL. Not necessarily. There are isolated cases. It is like selecting the right conditions; you can get a certain thing. If you happen to select a certain strain of animals you can produce an effect. Actually this is done in cancer research. You preferentially select a cancer susceptible strain. You can also inadvertently select certain animals that may have a tendency toward sterility. We know the situation exists because we observe it in man, that certain people are sterile. You can produce the same effect in animals. If you happen to get a group of animals that have these genetic tendencies, you can produce these effects. You attempt to rule this out by selecting a conrol group to eliminate the variability here.

If I may continue, nutritional inadequacies in the diet are well recognized and certain physiological aberrations are noted from a nutrient deficiency. This situation is easily corrected by addition of the nutrient lacking and is quite different from a toxicity produced by the presence of certain toxic compounds in foods.

I gave you the example a while ago of the oxalic acid content in spinach. In the remarks that were made yesterday, in Mr. Morse's testimony at page 4, there was a reference ot the Highland Park meeting, and I attended that meeting. This was at Highland Park, Ill., a contractors meeting in January 1959. At that time many of the investigators recognized that there was not any toxic effect due to feeding of irradiated foods to animals, and I made that summation for the Surgeon General.

That concludes my remarks on the wholesomeness part. I have a few other statements to make.

Representative VAN ZANDT. Doctor, the Army position as conveyed to us yesterday in testimony points to the fact that they lean and lean alone on meat, primarily beef. In your opinion, do you think if you are going to evaluate this overall program, that you should confine your study to one particular item or should you apply it across the board to the many items?

Dr. KRAYBILL. That Army I think feels that way because if you analyze the master menu that the Quartermaster puts out, beef is served quite often to the soldier. I don't know the exact percentage. It is pretty high. If you are to consider that pork and chicken and fishery products are important, then we have an area of interest. So far beef has given us, shall we say, somewhat unsatisfactory results from a palatability standpoint. There are certain people who people who claim that a so-called irradiated "brown and serve" item has interest. This is what I mean by "brown and serve"; a meat that has been preheated and then irradiated. I have tasted some pork that was preheated and subsequently irradiated, and this product in my estimation was superior to a canned pork (that is a pork that has been processed at 245° F.).

Representative VAN ZANDT. What about dairy products, principally butter?

Dr. KRAYBILL. Dairy products do not lend themselves very well to radiation processing. I should make a correction here, in that the late Dr. Proctor and his group at MIT, have discovered a very interesting technique on milk irradiation where they can vacuum-distill and radiation-process milk simultaneously. They can remove by vacuum distillation certain off-flavor components. This product I

have tasted and it is quite respectable. This milk is, I would say, as good as the fluid milk that we have on the market today. Whether this would be economic, I don't know. I think it would be rather expensive to use this treatment.

Representative VAN ZANDT. What about potatoes? You are familiar with how the armed services in the many frontiers throughout the world use potatoes.

Dr. KRAYBILL. Potatoes have some promise. There is some reluctance in this country to fully accept it. They feel there are competitive methods. There are certain chemicals that can inhibit sprouting. We did note in the meeting I attended at Harwell, England, last year, and again at the international symposium we had at Cambridge, the fact that some European countries have looked upon this with favor, particularly Russia and Poland, who are considering this process very seriously.

Representative VAN ZANDT. Principally the irradiation eliminates sprouting, is that correct?

Dr. KRAYBILL. Yes.

Representative BATES. You say the late Dr. Proctor?

Dr. KRAYBILL. Yes.

Representative BATES. How long ago did he die?

Dr. KRAYBILL. I have been informed it was October.

Representative BATES. That is B. E. Proctor?

Dr. KRAYBILL. Dr. Bernard E. Proctor.

Representative BATES. I have a draft copy of the report I thought was off the press with his name on it.

Dr. KRAYBILL. We attended a meeting at Cambridge the last of July and I talked to him then. It was this fall that he died.

Representative BATES. Are you familiar with his exprience with fish? They had a contract at MIT.

Dr. KRAYBILL. Yes. I read some of his reports.

Representative BATES. How did that turn out?

Dr. KRAYBILL. Very good. The results on fishery products look quite promising as Dr. Aebersold pointed out yesterday. I would like to make some comments with reference to technology.

POTENTIAL AREAS OF APPLICATION OF RADIATION PROCESSING OF FOODS

The Department of Army program has been centered upon the development of a successful radiation sterlized product, particularly meats. Whereas studies to date on radiation sterilized beef are somewhat disappointing insofar as attainment of a highly acceptable product, scientists in the meatpacking industry believe that important developments may come in this area. Certain investigators have already shown that preheating meats such as pork or beef prior to irradiation yields ultimately an irradiated product that has good texture and flavor. While further research may be necessary on beef, it has been shown by several laboratories that irradiated "brown and serve" pork is quite superior to heat processed pork (245° F.) with respect to flavor and texture. Chicken and fishery products respond well to radiation sterilization and would be quite acceptable to the military as well as civilian consumers.

As the result of the extensive research and development programs supported by the Department of the Army and from a survey of the food industry, radiation preservation of foods has revealed some products that are of interest to the military and of importance for early commercialization. For commercialization low dose radiation treatment offers more immediate promise since such foods respond quite favorably to radiation processing. In addition the radiation processing costs approach competitively the processing costs of other preservation methods. From the standpoint of economic and technical feasibility, and pending wholesomeness clearance by the Food and Drug Administration, the following list is representative of products that might be marketable in late 1960 or 1961.

Perhaps I am a little optimistic on that date. It may be 1961 or 1962. To name a few, and I may be challenged on some of these, I would comment, however, as we see them from literature and industry-wide survey.

1. Fishery products, radiopasteurized.
2. Chicken, radiopasteurized.
3. Fruits, radiopasteurized.
4. Egg solids, radiopasteurized for salmonella destruction.
5. Pork, radiopasteurized for shelf life extension and trichina control.
6. Frozen processed or prepared foods radiopasteurized for bacterial control. By this I mean the type of frozen foods you see in the food stores, such as TV dinners and products of that sort, that may be high in bacterial count.
7. Pet foods, radiopasteurized.
8. Radiation sterilized "brown and serve" meats.

Leadership in the field of radiation sterilization and more particularly in the cheaper processing area of low radiation dose treatment for extension of shelf life of fruits, fish, and chicken is important in that it provides the foundation for major advances in this technology in Central and South American countries. We have firsthand information on them. In many of the underdeveloped countries, conventional methods of canning, freezing, and spray drying are nonexistent. Extension of shelf life, for example, of fish or chicken for even a few days by means of irradiation would mean a higher quality of product for the population that is underfed, less food spoilage or wastage and, most important, reduced sickness from food spoilage.

Representative VAN ZANDT. Doctor, at this point, based on this paragraph that you have just read, is it not proper to say this would be a great contribution to President Eisenhower's atoms-for-peace program?

Dr. KRAYBILL. It definitely would. I think as someone indicated yesterday that we have assumed the leadership in this field, and this is something to consider very seriously. I think our decision on the center that was read in the European press affected them very greatly. It is somewhat academic, I think, to say that this does not affect a research program, because we have gotten letters from four or five people from Europe who said that already they have had difficulty in getting funds to even carry on a university type research program.

Representative VAN ZANDT. Some of us on this committee have traveled extensively selling to the peoples of the nations we visited

the President's program of atoms for peace. One of the items of the program was irradiation of foods. Yesterday I was thinking of our visit to Nigeria, to French Equatorial Africa, and India, and Pakistan. Now you bring up Central and South America. This is really a program you can sell to these people. I just cannot understand the decision of the Army to cancel a program or even downgrade it, as they have.

Dr. KRAYBILL. I think the only thing that is prohibiting some of these countries—I mention South America—is the funds. This is the big problem in any project. They have a little different food-processing situation than we have in the United States. As I pointed out, they need something to extend shelf life on some of these products. They are definitely interested. Other countries in Europe, are interested in fruits, for example, such as citrus fruits, they would like to have a method that would extend the shelf life of a product such as this.

Representative PRICE. Doctor, as I understood the presentation of AEC yesterday, and the references to the interdepartmental committee report, they were thinking more of a program of pasteurization as against sterilization. How would that fit in with this paragraph here?

Dr. KRAYBILL. I think the interdepartmental committee, the report given by Dr. Aebersold, I would endorse, because of our survey and our findings. There seems to be potential interest in this area, because there are so many things you can do from a technological standpoint. It may cost just a little bit more than processing by heat to start out, but I think ultimately the cost would be quite competitive, as I indicated. The cost of one-tenth of a cent a pound or 0.05 cent a pound is fairly low for food processing.

Representative PRICE. Would this program take care of the situation that you discussed in the eight items which you have there, and the problem of leadership in the field of radiation for the underdeveloped countries? Would it help in that type of a program?

Dr. KRAYBILL. It most definitely would. I think our European colleagues were quite shocked, and they wondered what happened, because they just attended a meeting this summer at Cambridge where an optimistic picture had been given on the program.

Representative PRICE. Do you think you need go no further than a mere pasteurization program?

Dr. KRAYBILL. At the moment I believe considerable emphasis should be put on that type of processing other than the "brown and serve" items. I think there is some hope for what we call combined treatment, where we use heat and radiation processing. Perhaps Dr. Urbain will speak about this technology.

Representative DURHAM. Doctor, you have spent a considerable sum of money in this field already. You have been at it since 1954. How would you sum it up as to its benefits to science? You have brought out here that you can take out certain items, you destroy certain vitamins. Did you know those things at the beginning of this project as being a factor?

Dr. KRAYBILL. No, we did not in the sense that this is entirely a new concept in food technology. There was some basic work done back in 1950 and 1951, work by Dr. King at Columbia University, and Dr.

Proctor at MIT and these projects were supported by AEC, and they showed that they had certain effects on vitamins.

I would like to point out here that these effects are no greater and in many cases the destruction of vitamins by radiation processing is not as great as that by heat processing.

Representative DURHAM. You can state as a fact that this has had a great deal of benefit to the scientific community?

Dr. KRAYBILL. It has.

Representative DURHAM. It is not all wasted as we sometimes get accused of?

Dr. KRAYBILL. No, it is not.

I would like to emphasize my earlier statement, in the early years of the program they thought it would be a panacea. It is not.

Representative DURHAM. We get that idea with a lot of things. We get that on space and many other things.

Dr. KRAYBILL. I think the term has been applied in the press and a lot of people have used it, cautious optimism. We know pretty much now what areas seem to appear as having great potential in the future. I for one feel that this low dose radiation treatment that was referred to in this Interdepartmental Committee Report has some promise and should be definitely looked into.

Representative DURHAM. In my travels over the past 20 years or more throughout the countries in South America and Asia, and other countries, one of their greatest necessities is nutritional value, something that they can depend on. When we initiated this project, I had high hopes that this would be one of the additions that we could call to the world as being an outstanding scientific development in trying to help these underdeveloped countries.

Dr. KRAYBILL. Yes.

Representative DURHAM. They certainly cannot produce without nutritional value.

Dr. KRAYBILL. Yes. I think the UNICEF and the World Health Organization has an excellent program concerned with nutritional problems.

Representative DURHAM. What I fear, with the publicity such as you see in the paper this morning, is that this may in a way affect our going forward with the program. From the evidence produced here, to me it is something worthwhile of being continued.

Dr. KRAYBILL. Yes.

Representative BATES. What is the prospect of developing a small mobile inexpensive radiation unit?

Dr. KRAYBILL. We have designed for such a unit.

Representative BATES. Let us take the case of fish. You will still require ice, will you not?

Dr. KRAYBILL. In talking about extension of shelf life; extension of shelf life is considered in the United States as product under refrigeration. Some people have spoken of extension of shelf life in ambient temperature. Like in Central and South American countries, I don't think they are going to get too great an extension of shelf life at ambient temperature, however this small extension may be quite important.

Representative BATES. You still have to have it under 40°.

Dr. KRAYBILL. Forty degrees or below as refrigerated product. It has been proposed using radiation and antibiotics as a combined treatment.

Representative BATES. Food and Drug would not go along with that?

Dr. KRAYBILL. Not at the present.

Representative BATES. They do in Canada.

Dr. KRAYBILL. Antibiotics have been approved for some products, haven't they?

Representative BATES. For fish?

Mr. ROE. We have given tolerances for antibiotics residues for certain fish products and certain poultry products where a showing was made that the residues remaining would be destroyed on cooking. That is a very limited use as a preservative in the preparation. We would look very carefully at any proposal for introduction of antibiotics generally into foods for obvious reasons.

Representative BATES. Have you done it on ocean perch?

Mr. ROE. No, sir.

Representative BATES. Are you looking at that one?

Mr. ROE. Not that I know of at the moment.

Representative BATES. You were a year ago.

Mr. ROE. I think it was subject of a proposal that was before us. I think that was not suitable at that time. (A tolerance of five parts per million for residues of chlortetracycline on raw vetebrate fish, shucked scallops, and unpeeled shrimp has been established to permit the application of this antibiotic to retard spoilage in fresh caught, whole, headed and gutted fish, shucked scallops, and unpeeled shrimp.")

Representative PRICE. How about cranberries.

Mr. ROE. Cranberries are of course in a somewhat different category. Antibiotics were not involved there.

Representative BATES. Isn't Canada using it for ocean perch today?

Mr. ROE. I am not sure. Canada did permit some usage on fishery products. I am not certain of the status of it or the extent of it.

Representative BATES. They are bringing in over 100 million pounds of fish a year into the United States. Do you check and make certain that they have not used these antibiotics?

Mr. ROE. Yes, sir. We have checked on imports and there have been some detentions on that account, and there have been some discussions between the two countries as a result thereof.

Representative BATES. What do you do when you find it?

Mr. ROE. Don't admit them.

(A letter from Mr. Roe, clarifying his remarks, follows:)

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE,
FOOD AND DRUG ADMINISTRATION,
Washington, D.C., January 20, 1960.

Hon. CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: In the course of the hearings held on January 14 and 15, some questions were raised as to the status of the use of antibiotics for the preservation of food. I indicated that the only approved uses of antibiotics in foods, so far as the Food and Drug Administration is concerned, are certain limited uses in poultry and in fishery products. In order to clarify statements

made at that time I should like specifically to indicate the tolerances that have been established for particular products.

Tolerances of 7 parts per million have been established for residues of the antibiotics chlortetracycline and oxytetracycline in raw poultry. These tolerances were established to permit the use of the antibiotics in the cooling tanks in poultry establishments as preservatives to inhibit spoilage organisms. These residues are destroyed under the usual cooking temperatures to which poultry is subjected.

A tolerance of 5 parts per million for residues of chlortetracycline on raw vertebrate fish, shucked scallops and unpeeled shrimp has been established to permit the application of this antibiotic to retard spoilage of fresh-caught whole, headed, and gutted fish, shucked scallops, and unpeeled shrimp.

Sincerely yours,

ROBERT S. ROE,
Director, Bureau of Biological and Physical Sciences.

Representative PRICE. Will you proceed.

Dr. KRAYBILL. May I make a closing comment, then?

The first and most important reason for such a center is that it is functionally required.

Representative PRICE. When you say such a center, what do you mean?

Dr. KRAYBILL. A radiation research center, modified somewhat from the one proposed for the Army at Stockton, Calif.

The first and most important reason for such a center is that it is functionally required. There is not available to the program at this time any cobalt 60 facility which would be deemed adequate for irradiating food or any radiation facility which provides the source versatility for testing the effects of different parameters such as dose uniformity, dose rate and dwell time.

For effective continuation of the food irradiation program such a center, which can provide adequate research facilities and can disseminate practical irradiation techniques, is essential.

Such a center, moreover, is important for the maintenance of U.S. leadership and worldwide prestige in this field. The cancellation of the USAIRC facility was a severe blow to this prestige, all the more so because of distorted versions of this action which were reported in foreign countries. There has been a considerable disillusionment in European countries who had programs based on U.S. leadership. Paradoxically, the program for a cooperative European center is rapidly gaining momentum and the center of gravity of radiation developments will undoubtedly shift to Europe unless adequate steps are taken to bolster the U.S. position.

Representative PRICE. Doctor, could you cite any evidence to support your statement that there has been disillusionment in European countries?

Dr. KRAYBILL. I made a brief reference to that earlier in that people that I talked to who attended the Cambridge meeting, came over here with somewhat high hopes on the program. Dr. Erickson was one I remember from Sweden who wrote to us, I believe in November or December, and who said he was quite shocked that this sort of thing had happened. He wanted to know what the facts were, that he already had difficulty in getting funds to continue his own research program in Sweden.

Representative PRICE. He was shocked that this thing happened?

Dr. KRAYBILL. Yes; the deferring of the center.

Representative PRICE. When was that when he was here?

Dr. KRAYBILL. He had written a letter. He was here in July to attend the Cambridge meeting, this international symposium.

We have also gotten communications from Dr. Shea, who is with our group, who is on duty now with the OEEC in Paris, and he has made a survey of the situations in Spain and Portugal, Italy, Germany, and the Scandinavian countries.

Representative PRICE. He seemed to have more accurate information a lot earlier than we were able to get on this even though we were directly in communication with the Army to find out what their plans were.

Representative BATES. Have you any indication of going ahead with this? You indicated a shift from the United States to Europe.

Dr. KRAYBILL. Our representatives in Europe have indicated to us that there is tremendous interest and they are considering at the present time, I believe, a radiation center. I don't know where it would be placed. I don't know whether it would be in Paris or Berlin.

Representative BATES. Have they been considering that since the Army decision?

Dr. KRAYBILL. Yes, they are still discussing it.

Representative PRICE. We will try to build it for them.

Representative DURHAM. How about the English work? How broad has it been in this field?

Dr. KRAYBILL. They started in this program before we did. When we got into it, in 1953, or before that, they got back into the work. At our meeting we had over a year ago at Harwell, I believe the British are concentrating largely on low dose treatment. They are considering radiation processing of food items below 1 megarad or 1 million rad. This is essentially what we call low dose treatment.

Representative VAN ZANDT. Doctor, a moment ago you were explaining a letter received from someone in Europe that involved a survey of several countries. Could you repeat that again and complete the statement for the record?

Dr. KRAYBILL. That was Dr. Kevin Shea who was with Curtiss-Wright and has been on loan to the OEEC, and has headquarters in Paris. He has written us letters concerning the interest in Europe. He first wrote us about the shock, or I should say concern over the news release concerning the deferral of the plans for the center in this country. This came, as I say, as a surprise to them because of the previous information they had gotten by attending a meeting a few months preceding that in Cambridge.

Representative VAN ZANDT. What countries did his survey include?

Dr. KRAYBILL. He has made a survey in Spain, Portugal, France, the Netherlands, and I think at the present time he is in the Scandinavian countries.

Representative PRICE. Doctor, would the plan as outlined in the report of the interdepartmental committee take up the slack that England anticipated our country would pursue? Would that fulfill the type of program they anticipated or looked forward to in this country?

Dr. KRAYBILL. I think the type of program that Dr. Aebersold outlined would pretty much coincide with the sort of thing that some European countries are doing, particularly England. I believe that is correct.

Representative PRICE. Would it fulfill the European idea of the program that we had indicated to them we would follow?

Dr. KRAYBILL. I believe in some countries; yes. I cannot make a general statement that this would satisfy everybody's requirements. I think this is particularly true with reference to England.

Representative BATES. Doctor, would you comment on that MIT recommendation? I think 10,000 and 50,000 curie sources established for marine purposes? You are familiar with the report.

Dr. KRAYBILL. I took a glance at that report.

Representative BATES. They indicated the immediate construction of two interim radiation sources of 10,000 and 50,000 curies.

Dr. KRAYBILL. Yes.

Representative BATES. Would you care to comment upon that recommendation?

Dr. KRAYBILL. I think that would serve a very useful purpose, to have a gamma radiation source. I don't know whether the curies mentioned here are high enough, but that is beside the point.

Representative BATES. That is for substerilization?

Dr. KRAYBILL. Yes, but the application, I think, that has been recommended here is very important.

Representative BATES. You would suggest that even though the center goes ahead, because it is a different type of matter?

Dr. KRAYBILL. Yes. The center may be directed toward other items. If the center would handle sterilized products, that is what that would be useful for. I think these small irradiators or even mobile irradiators would be quite useful. This is what the Department of Agriculture is considering, a mobile irradiator.

Representative BATES. How would it be mobile? Within a fishing town to go from one processing plant to another?

Dr. KRAYBILL. Yes. It could be transported, let us say, from Boston to Seattle.

Representative BATES. You mean from Gloucester to Seattle.

Dr. KRAYBILL. All right, I stand corrected.

Another thing it could be used for is irradiation of fruits in California during one season, and then brought to Minnesota to handle grains or something of that sort. This would be quite useful.

Representative PRICE. In your opinion is the center essential even in the plan as discussed in the Interdepartmental Committee report?

Dr. KRAYBILL. Is is what, sir?

Representative PRICE. Is it essential for further research and development even in the watered down program?

Dr. KRAYBILL. Yes. We like to think of what we call a radiation research center. There are all kinds of terms applied to this—a pilot plant, or a modified center wherein a lower number of curies for the cource, is contemplated than that originally planned. We need a center where one could study technical feasibility and get some good economic cost figures.

Representative PRICE. In other words, it would be essential in your opinion even in the civilian program as discussed here yesterday afternoon?

Dr. KRAYBILL. It could be quite versatile. It could handle all interests, military and civilian alike.

Representative PRICE. It could. But do you regard it as being essential to the success of the research and development even in the civilian program discussed here yesterday?

Dr. KRAYBILL. That is a question that is difficult for me to answer. I know it could apply to the civilian program very nicely and it could apply to the military. Which agency wants to take over this thing, I am not prepared to say.

Representative PRICE. Regardless of agency, you say it is an essential instrument?

Dr. KRAYBILL. It is.

Representative PRICE. I am trying to find out whether or not you also thought it was essential in the civilian program which was discussed here yesterday as a replacement for the deferred program.

Dr. KRAYBILL. The answer to that question is that I think it would be.

Representative PRICE. In other words, it is strictly a research and development tool.

Dr. KRAYBILL. That is right.

Representative PRICE. Which you feel is necessary in research and development on this program, whether it is civilian or military.

Kr. KRAYBILL. That is correct.

Representative VAN ZANDT. Doctor, you heard the testimony yesterday which gave indications there may be literally months expire, if not years, before the irradiation center can be authorized and become a reality. What will this period of lack of activity mean to the program as a whole?

Dr. KRAYBILL. I can only guess as well as everyone else in this room. I think it would be my estimate that there would be a tremendous lag in interest and ultimately your research program would be dissipated and probably cut off. It may take many years for the United States to get back into this field again.

Representative PRICE. Mr. Ramey.

Mr. RAMEY. Could the irradiation center planned for Stockton be adapted without too much difficulty to take care of a combined civilian and military program?

Dr. KRAYBILL. Very definitely. I think there has been some thinking along these lines as to a modified version of the so-called HIFI setup as we know it.

Mr. RAMEY. How long would it take to adapt this design and come up with a modified proposal if it were given some priority as to the desirability of doing this?

Dr. KRAYBILL. Almost immediately, I would say, because some thinking has been given to this almost 2 months ago. The modification could be handled very quickly.

Mr. RAMEY. When you say some thinking, has that been done by the design contractor?

Dr. KRAYBILL. More than thinking. I think a report has been written.

Mr. RAMEY. There is a report. Has that report been made to the Quartermaster Corps or to the AEC?

Dr. KRAYBILL. I believe it has.

Representative PRICE. The committee will request the report and any other reports that are essential to the deliberations of the committee on this subject.

(Correspondence concerning the report follows. The entire report dated December 14, 1959, entitled "Revised Army Program on Food Preservation by Ionizing Energy" will be found in app. 1, p. 133. A reviewed and modified report, dated March 11, 1960, is also in app. 1, p. 133.)

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C., February 26, 1960.

Mr. RICHARD S. MORSE,
Director of Research and Development, Department of the Army, Washington, D.C.

DEAR MR. MORSE: This will confirm the telephone request of Mr. John T. Conway, assistant staff director, Joint Committee on Atomic Energy, to Dr. John L. Schwab, your special assistant, on this date, for a report pertaining to a modified version of the Army Food Irradiation Center referred to during the Joint Committee's hearings on January 15, 1960, and which Congressman Melvin Price had requested.

You will recall that Dr. Herman F. Kraybill, senior scientist, nuclear radiation department of the Curtiss-Wright Corp., who was former Deputy Project Leader in the Office of the Surgeon General, Department of the Army, in testifying before the Joint Committee, first brought this report to the committee's attention. Dr. Walter M. Urbain, Director of Engineering Research, Swift & Co., and Chairman of the National Research Council, Subcommittee on Radiation Preservation, also made reference in his testimony before the Joint Committee that same day to a decision by the Army for a smaller facility.

Representatives of your office were present during the hearing when Congressman Price stated that the committee would ask for the report. I, that same day, spoke with your special assistant, Dr. Schwab, and, on behalf of the committee, requested the report. I would appreciate it therefore if, in accordance with the committee's wishes and my request of January 15, that the report be furnished to the Joint Committee.

Sincerely yours,

JAMES T. RAMEY, *Executive Director.*

DEPARTMENT OF THE ARMY,
OFFICE OF THE DIRECTOR OF RESEARCH AND DEVELOPMENT,
Washington, D.C., March 16, 1960.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy, The Capitol, Washington, D.C.

DEAR MR. RAMEY: I regret the delay in responding to your request of February 26, 1960, for the Army's report on the modified version of the Army Food Irradiation Center referred to during the Joint Committee's hearings on January 15, 1960.

Enclosed herewith is a copy of the proposed revised Army program as submitted by the Quartermaster General for approval and referred to in the January 15 hearings. Since its submission to the Army staff in early December, it has been reviewed and modified. The program, as finally approved in my office on March 11, is attached as enclosure 2.

Sincerely,

RICHARD S. MORSE,
Director of Research and Development.

Representative PRICE. Even if the implications that were made here yesterday as to the physiological effects of irradiated food were correct, or you had this deep suspicion, would it be advisable or even essential to have this test center in being? Would it help to prove out some of these things or to disprove.

Dr. KRAYBILL. I believe this is pretty much like the situation that Dr. Siu described yesterday when in the early days of the program they wondered whether they should start the toxicity program at the same time the technology program got underway. They wanted to set up a schedule so that everything would work out and they would

get results simultaneously. I believe if you had such a center you could still go ahead because I certainly am not doubtful about these animal tests. Perhaps in 6 months or a year we will have the complete answer even on this heart defect. Certainly I don't think there is anything too alarming here that should hold up any plans or thinking on this center. The modified center is not a full-fledged food processing plant. It is a research and development.

Representative PRICE. It is not a production plant. It is a research tool.

Dr. KRAYBILL. It is a research and development facility.

Representative VAN ZANDT. At this point my attention has been called to a colloquy that took place in February-March of 1956 when this subject matter was before the so-called Price subcommittee. At that time I asked this question and made this statement:

> We had some testimony presented here several weeks ago that led me to believe that they wanted to use it (speaking of this HIFI project) for purposes other than irradiating foods.

Mr. COLE said:

> What would those other purposes be?
> Mr. DAVIS. I am not sure what those other purposes are.
> Mr. VAN ZANDT. Taking care of fungi in leather and clothing, and so forth. In other words, the Army had other uses.

Are you familiar with the application of irradiation to the elimination of fungi, mold, and so forth?

Dr. KRAYBILL. I have not been connected with that work. You bring out an interesting point, however, not only with respect to foods, but hospital supplies. This is a very promising field. You can treat mattresses and linens and such things as syringes and sutures. A a matter of fact, one pharmaceutical company today, I believe, is using this method in their production of sutures. They are using radiation.

Representative VAN ZANDT. Doctor, the testimony that we received at that time indicated very definitely they had other uses for this reactor.

Dr. KRAYBILL. This, as I describe, would be other uses. Other than foods there would be such things as hospital supplies. This has been proven out technically and I think it is economically feasible.

Representative VAN ZANDT. By the expression of proven out, you mean it is practical.

Dr. KRAYBILL. It is practical. Publications will verify this. I would like to point out here that I guess the first radiation processing application in the world is that in Australia, where they are radiating goat hair to take care of anthrax. They are getting cobalt from England. I think Westminster Carpets is the industry who are using this process in treatment of goat hair. So it looks like they beat us to the punch.

Representative VAN ZANDT. In other words, our Government has suspended a project which would produce some results Australia is already taking advantage of?

Dr. KRAYBILL. In effect, yes.

Representative PRICE. Would you complete your statement?

Dr. KRAYBILL. Yes, sir. The economics of radiation processing has frequently been questioned. It is certainly true that radiation costs a

great deal more than steam. But radiation processing is by no means too expensive for industrial exploitation—radiopasturization processes are reliably estimated at a few tenths of a cent per pound and radiosterilization process at a few cents per pound. So far, of course, these are pen and pencil estimates, but with a versatile radiation center the essential factors in such costing can be reduced to fact.

Representative PRICE. Thank you very much.

Representative VAN ZANDT. Doctor, with your broad background of knowledge in this field—I am thinking now of the application of radiation to the elimination of mildew, fungi and insects, and so forth, when it comes to the President's program of atoms for peace, these items mentioned can really be something worthwhile. I am thinking of a few million dollars we can spend, the results we would enjoy, and then compare it with the billions of dollars we spend today on our foreign aid program.

Dr. KRAYBILL. I agree.

Representative PRICE. Are there any further questions of Dr. Kraybill? If not, thank you very much.

Dr. KRAYBILL. Thank you.

Representative PRICE. The next and concluding witness will be Dr. Walter Urbain, director of engineering research, Swift & Co.

STATEMENT OF WALTER M. URBAIN, DIRECTOR OF ENGINEERING RESEARCH, SWIFT & CO., CHICAGO, ILL.

Dr. URBAIN. Thank you, sir.

Representative PRICE. If your assistant is expected to answer any questions, will you identify him for the committee so we may direct questions to him occasionally?

Mr. URBAIN. Mr. Wilbur C. Davis is with me, from our Washington office. If I may suggest, he is here to lend me moral support.

I am Walter M. Urbain, director of engineering research, Swift & Co., Chicago, Ill. I am here as a result of a telephone invitation of Commander Edward J. Bauser, of the staff of the Joint Committee on Atomic Energy (Congress of the United States), made to me on January 9, 1960, and confirmed by letter of James T. Ramey, executive director, of the same date.

My professional training is in chemistry; I hold a bachelor of science degree and doctor of philosophy in chemistry from the University of Chicago. I have been employed by Swift since 1933, working in the research department.

I am here to make a statement to the committee at its public hearing on the Army food irradiation program being held this present date of January 15.

My statement to the Joint Committee on Atomic Energy regarding irradiation preservation of food reflects experience with Swift & Co. in carrying out research in the field since 1949. Swift & Co. became interested then in this process for the following reasons:

1. Despite a variety of available conventional methods for the preservation of food products, such as meat, microbial spoilage of foods was occasioning a number of problems and irradiation preservation appeared to offer a new approach to their solution.

2. Irradiation appeared to accomplish its bactericidal action with a minimum alteration of the normal characteristics of the food.

3. Irradiation offered possibilities of new or improved products because it offered control of spoilage micro-organisms independent of procedures involved in the preparing of foods for the table. Specifically, it offered possibilities of shelf stable products which were heated less than is done conventionally.

4. Costs for irradiation, while somewhat uncertain, appeared to fall within a reasonable range. The advent of atomic energy and the availability of radioactive gamma ray sources derived therefrom greatly encouraged us in that view.

Results of our studies showed the following:

(*a*) Radiation can destroy micro-organisms responsible for spoilage.

(*b*) With due allowances for the difference in penetration and absorption, electron beams and gamma radiation gave substantially the same results.

(*c*) The amount of radiation required to obtain sterile meat products was at least 2 million rads. A lesser quantity of radiation, by destroying a percentage of the spoilage micro-organisms present, increased the life of the food product held under normal storage conditions.

(*d*) Radiation in an amount sufficient to destroy micro-organisms did not destroy enzymes and enzyme spoilage of some foods could occur on storage. Hence the need for another agent to control enzyme spoilage.

(*e*) Radiation can produce changes in taste, appearance, and texture of a given food. The exact effect depends upon the food in question, the amount of radiation, and conditions of treatment.

(*f*) Most important among the radiation-induced changes in food was the development of a typical off-flavor resembling scorching. This off-flavor adversely affects the palatability of the food, and at sterilizing levels make most foods unacceptable. Exceptions appear to be chicken, fresh pork, and certain organ meats, such as liver. At less than sterilizing levels, the flavor development was generally too small to be significant in acceptability.

(*g*) A feeding study conducted with white rats and employing irradiated ground beef, revealed no abnormalities, ascribable to the irradiated products, in the test animals which were carried through three generations.

Representative VAN ZANDT. What period of time is this statement based on?

Dr. URBAIN. Our results were published in 1955.

Representative VAN ZANDT. How much laboratory work preceded that?

Dr. URBAIN. Of the order of 3 years.

Representative VAN ZANDT. Since 1955, has it continued?

Dr. URBAIN. No, we have discontinued those tests.

Representative VAN ZANDT. But your finding that was revealed in 1955 is the basis of this statement?

Dr. URBAIN. That is correct.

Representative PRICE. Where did you make your laboratory findings and what radiation facilities did you have?

Dr. URBAIN. At that time our earliest work was done with an electron generator which was located in Brooklyn, N.Y. Later we used a radiation source of the General Electric Co. for a short period at Schenectady, N.Y., and then we had such a unit installed in our own laboratories.

The feeding tests were conducted in our own laboratories.

Representative VAN ZANDT. Doctor, how many scientists were involved in this program?

Dr. URBAIN. The published article is authored by six individuals, and there is acknowledgement of a considerable number in addition to those who participated.

Representative VAN ZANDT. Would you object if we made this report here a part of our record?

Dr. URBAIN. No, sir. It is a publication.

Representative PRICE. Without objection it will be made a part of the record.

(The document referred to appears in app. 6, p. 646.)

Representative PRICE. Did you have any outside contract studies made?

Dr. URBAIN. With other individuals?

Representative PRICE. Yes.

Dr. URBAIN. Only with the Electronized Chemicals Corp. from whom we in effect rented their radiation source. The work was all done in our own organization.

I might add that some of the histopathological work in connection with the study was done at the University of Illinois.

Representative PRICE. Did you have any university study made?

Dr. URBAIN. For the histopathological work we did.

Representative PRICE. Would you proceed.

Dr. URBAIN. Apart from other considerations, the chief reason we did not undertake the commercial preparation of sterilized irradiated meats was their lack of acceptability. The organoleptic changes were too great to consider marketing such products. It was felt that consumer acceptance would be poor.

Serious consideration was given to the use of less than sterilizing quantities of radiation, but other important problem areas were encountered in this type of application, viz:

1. Radiation controlled microbial spoilage but failed to control other changes, principally of a chemical nature, which affected the appearance of fresh meats. Therefore, the marketable shelf life was not extended.

2. The second problem area lay in the economics of the process where the irradiation and associated costs offset any economic gains.

While recognizing the existence of other problems, it was our view that improvement of acceptance of irradiated products was primary. Much of our research at Swift has been directed toward controlling the undesirable organoleptic changes in meats. We have attempted every procedure which we believed would be helpful. Our findings have been generally unsuccessful. We have reached the conclusion that a solution can lie only in an understanding of the process and with that the development and application of suitable control measures. This is basic research for which an industrial organization such as ours is not properly equipped. Our research expenditures on radiation preservation to date exceed $600,000.

In 1953, the U.S. Army became interested in irradiation. I was a member of the National Research Council ad hoc committee which recommended that the Army undertake research on irradiation preservation. Ever since the Army instituted its program, Swift & Co. has offered assistance. Mr. H. S. Mitchell, formerly assistant vice president of Swift & Co., was a member of the NRC subcommittee on radiation preservation for the 3-year period from 1953 to 1956. I have been a member since 1956 and currently am chairman of the committee. Swift & Co. has held a no-cost contract with the Army Quartermaster Research and Engineering Command since 1954. We have, in addition, a cost contract starting January 8, 1960, for 1 year.

We have followed the Army program with great interest and have noted that, in general, the Army has confirmed findings obtained by our own efforts. Because their program has been a larger one than ours, they have gone far beyond our efforts and have investigated many areas we could not, and others much more intensively than we could.

Our present appraisal of radiation preservation may be given as follows: In our opinion, the process is not ready for commercial use. In our judgment, its application at the present is limited by technical factors as follows:

1. At sterilizing levels to those few foods which naturally do not develop an off flavor or otherwise undergo serious organoleptic change. Fresh pork and chicken heated to inactive enzymes and placed in a container such as a can may be possibilities. Oysters and shrimp likewise appear satisfactory.

2. At less than sterilizing levels to a number of foods. Currently in the United States fresh meat does not appear to be one of those, partly because of presently available satisfactory methods.

3. By lack of approval for use from the U.S. Food and Drug Administration. (Work is underway to evaluate the process to permit the FDA to pass on it.)

Representative VAN ZANDT. At that point, Doctor, would you say that the present rules and regulations of the Food and Drug Administration actually restrict experimental work in this field?

Dr. URBAIN. I don't believe they restrict experimental work; no, sir.

Representative VAN ZANDT. But they would restrict, of course, the placing of any of these products on the market.

Dr. URBAIN. That is correct.

Representative VAN ZANDT. They would have to meet the requirements of the Food and Drug people.

Dr. URBAIN. That is correct.

Representative PRICE. You may proceed, Doctor.

Dr. URBAIN. In these technically possible application, there are always the factors of useful purpose, economics, and consumer acceptance. These nontechnical areas have not been explored sufficiently, in our opinion, to know whether commercial value exists in use of radiation preservation as suggested above as technically possible.

We believe there is a need for new knowledge to secure irradiated foods with sufficient acceptance so that radiation-induced changes which are not desirable can be prevented. The most likely approach to this area, in my opinion, is through basic research. It is the type of research least likely to be carried out by industrial organizations

Looking at the picture as a whole, as far as I can determine, the food industry sees potential value in the preservation process. Companies, however, see the job as too big to be done individually, and it is suggested that what is needed is for some group to undertake at least part of the necessary research and make the results of it available to the entire food industry.

With this view, a Government-supported research program has logic. It is possible that the support of such a program by a military agency directed only to military objectives, would only indirectly benefit civilian usage. Therefore, there is reason for support of a program by a nonmilitary agency in addition to a military one.

It would appear logical also that if such a program existed, it would need suitable radiation facilities. Army experience has indicated that much confusion between investigators can result from a lack of well-coordinated radiation facility. Also there is considerable inefficiency entailed in using sources such as the Army has used to date. Therefore, there is reason for a central radiation facility or for centrally administered radiation facilities designed for food-irradiation purposes. Such a facility as is currently under consideration by the Quartermaster of the U.S. Army or by the AEC, would be most helpful in the conduct of a Government-supported program.

Representative PRICE. That is a fine statement, except the concluding line that it is not very much under consideration by the Army. It is "nonconsideration." It has been deferred. That is the facility you are thinking of, that the Army was thinking about at Stockton.

Dr. URBAIN. No, sir. I had assumed that was not to be available. I have been told that there is a somewhat more modest facility under consideration by the Quartermaster.

Representative PRICE. They have not presented any program here at all. They have just presented the deferral of a plan.

Dr. URBAIN. That is correct.

Representative PRICE. Are there any questions of Dr. Urbain?

Representative BATES. Doctor, what do you mean there is considerable inefficiency in using radiation sources such as the Army is using today?

Dr. URBAIN. Under our no-cost contract, we could use the radiation facilities in the Army program with the concurrence of the Quartermaster. We had some difficulties using the facility of the MTR reactor at Idaho occasioned largely by the distance involved and problems of communication.

Representative BATES. This is you, Swift & Co., using it?

Dr. URBAIN. Yes; under our no-cost contract. That is within our own experience. I have heard of similar difficulties from other investigators.

Representative BATES. What do you mean by much confusion between investigators? What is an instance of that?

Dr. URBAIN. At one time—again this was in connection with work as part of the Quartermaster program, there were different evaluations placed on the flavor development in irradiated beef by various investigators. Some regarded the beef as not acceptable and others as acceptable. There was a range of opinion.

Representative BATES. Investigators representing whom?

Dr. URBAIN. People in universities, people in various companies, all of them on the Quartermaster program.

Representative DURHAM. Your company made no effort to market any products under your program?

Dr. URBAIN. No, sir.

Representative DURHAM. The determination was made by what group? Was it a group of your own people as to the taste and quality?

Dr. URBAIN. In general, yes. There were limitations of the regulatory bodies of the Government which prohibited the marketing.

Representative DURHAM. The company made its own decisions to the marketability of the goods?

Dr. URBAIN. That is correct.

Representative VAN ZANDT. Doctor, were you keenly disappointed when you read the announcement of the Army suspending the program?

Dr. URBAIN. I have just said that I believe that central radiation facility is desirable for the conduct of the research. The exact nature of that facility is something that I do not feel fully qualified to pass on. The Army decision not to erect that facility unquestionably involves some information that I don't have available to me, so I do not feel qualified to comment on their decision.

I would like to have a central radiation facility, however.

Representative PRICE. Doctor, you intimated that you thought that the Army had in mind a smaller facility. What led you to that thought?

Dr. URBAIN. That was information which was transmitted to me by the Research and Engineering Command of the Quartermaster as a member of the NRC committee.

Representative PRICE. When they transmitted that information to you, did they contact you before they decided to defer the center program?

Dr. URBAIN. No, sir.

Representative PRICE. Why did they contact you afterward?

Dr. URBAIN. It was in connection with a revision of their program.

Representative PRICE. After they revised it, they contacted you?

Dr. URBAIN. It was during the revision they sought the guidance of the NRC committee regarding the revision.

Representative PRICE. Did they seek any recommendation of what the Research Council might think of deefrring the plan for the proposed center at Stockton?

Dr. URBAIN. No, sir.

Representative PRICE. But they did tell you that they were thinking of another center. They didn't go to your council for advice and suggestion. They just informed you what they were doing.

Dr. URBAIN. The information as transmitted to me was that a decision had been made—I should say to the committee.

Representative PRICE. That a decision had been made?

Dr. URBAIN. That is correct.

Representative PRICE. They did not go to the Council before and tell them what they were thinking about and wondering what the Council might suggest in connection with this matter and what recommendation the Council might make?

Dr. URBAIN. No, sir.

Representative PRICE. What is the nature of the Council as it related to the Army program? Did they frequently seek your advice and counsel?

Dr. URBAIN. This committee, as I have indicated, has been in existence for a number of years. It held several meetings a year at the request of the Research and Engineering Command of the Quartermaster. It regularly brought items to the committee that they sought guidance on.

Representative PRICE. Did they bring the original plan of the Stockton center to the attention of the committee several years ago?

Dr. URBAIN. Yes, they did.

Representative PRICE. Did they seek advice and suggestion at that time on this program?

Dr. URBAIN. Only in a general way.

Representative PRICE. At least they did seek some advice and they kept you informed on the plans.

Dr. URBAIN. That is correct.

Representative PRICE. Then when was the first knowledge you had that they were thinking about deferring the plan for the center which already was 2 or 3 years late in this program?

Dr. URBAIN. It was brought officially to the committee after the announcement.

Representative PRICE. After the announcement?

Dr. URBAIN. Yes, sir.

Representative PRICE. This announcement was on October 22, 1959?

Dr. URBAIN. Yes, sir.

Representative PRICE. At least you didn't get it ahead of this committee. You are about the only group that didn't get it ahead of the committee. But they did tell you, which they have not told the committee yet, they had a substitute facility that they were interested in.

Dr. URBAIN. This was the Research and Engineering Command of the Quartermaster.

Representative PRICE. They are thinking of a smaller facility?

Dr. URBAIN. That is correct.

Representative DURHAM. Doctor, you stressed the fact that you feel that there has to be a good deal more basic research done, and I think I agree with you. The expenditure of $600,000 by a private concern is not a small sum.

Dr. URBAIN. No, sir.

Representative DURHAM. You spent that money on the basis of what you felt was information that you were receiving that this would work out to the point where it would be of benefit to the Swift Co.?

Dr. URBAIN. That is correct.

Representative DURHAM. Getting back to your basic research problem, you make the statement here that there has to be some facility somewhere conducted by some group or Government agency to further carry out this basic research.

Dr. URBAIN. That is correct.

Representative DURHAM. In other words, progress will be at a standstill unless we do provide some type of facility.

Dr. URBAIN. It at least will be aided by the facility. I don't know whether it would completely stop.

Representative DURHAM. I mean it wouldn't complete the whole cycle of basic research. But certainly those facts which are important. For example, what could we have done without the wind tunnel and things like that in the development of the Air Force?

Representative VAN ZANDT. Doctor, contingent on the additional research, do you think this program contains the results we could really apply in the war on hunger we are hearing so much about today?

Dr. URBAIN. If I understand your question, you are referring to problems of food supply out side the United States.

Representative VAN ZANDT. That is right. I am thinking of India and Africa.

Dr. URBAIN. Basically modern civilization needs methods of preserving foods, either on a time basis or from location to location. Certain methods are available today in the United States. We have probably exceptionally good methods of preservation. Other countries, for example, do not have refrigeration facilites comparable with ours. Because of that lack, they have problems of preservation and distribution of foods. Irradiation is a preservation method. Assuming that certain things can be worked out to make it useful, and the economics justified, one would expect it to take some proper place as a preservation method generally. Its use in a particiular instance depends upon what is needed and how well it fits into those needs. I feel the answer to your question is that speaking generally it should fit into that picture.

Representative PRICE. It is still regarded as a research and development program. In order to prove the program out either successfully or as being something not worth pursuing further, you have to have the tools to do it; is that correct?

Dr. URBAIN. That is correct.

Representative PRICE. One of the essential tools is some sort of a research center such as was planned at Stockton; is that correct?

Dr. URBAIN. The concept of a research center, I think, is basic to the advancement of the field.

Representative PRICE. Mr. Bates.

Representative BATES. Doctor, a few moments ago Mr. Van Zandt talked about leather. Swift & Co., owns one of the largest, if not the largest, leather company in the country in A.C. Lawrence.

Dr. URBAIN. That is right.

Representative BATES. Have you done any work in the field of leather?

Dr. URBAIN. No, sir; we have not. We have confined our experimentation to food.

Representative BATES. You heard Dr. Kraybill this morning. Do you believe that the test to which reference has been made and the conclusions reached were unfounded?

Dr. URBAIN. I am not really certain I am undertsanding the reference.

Representative BATES. He indicated that the tests performed were unreliable and the conclusions drawn were unfounded. Do you agree with that?

Dr. URBAIN. I believe you are referring to the wholesomness studies. I am afraid I must disqualify myself. My area is physical chemistry and not nutrition.

Representative PRICE. Thank you very much, Doctor. We appreciate having your testimony. I think you have been very helpful to the committee.

Dr. URBAIN. Thank you, sir.

Representative PRICE. The Chair plans to hold the hearings open in the hope of getting further scientific testimony and also to give the various Government agencies involved here and anyone else who so desires, an opportunity to present their plans for the future in this program. So the committee will now adjourn subject to further call of the Chair.

(The following statements were received for the record:)

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE,
FOOD AND DRUG ADMINISTRATION,
Washington, D.C., March 8, 1960.

Hon. CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy,
U.S. Senate, Washigton, D.C.

DEAR MR. CHAIRMAN: At the time of the hearing on radiation preservation of food on January 14 and 15, the Joint Committee indicated that it would welcome a statement from the Department of Health, Education, and Welfare regarding its responsibilities in the matter of irradiated food and its participation in the Interdepartmental Committee on Radiation Preservation of Food.

Such a statement is enclosed.

Sincerely yours,

GEO. P. LARRICK,
Commissioner of Food and Drugs.

STATEMENT FOR PRESENTATION TO THE JOINT COMMITTEE ON ATOMIC ENERGY

This statement is presented in order to summarize and clarify the position and activities of the Department of Health, Education, and Welfare in the radiation preservation of food program. This program was inaugurated by the Department of the Army to study applications of radiation to food that might be useful particularly for military purposes. Scientists of the Food and Drug Administration have been informed of the program and the developments therein from the early stages. The late Dr. Elmer M. Nelson, Director of the Division of Nutrition, and Dr. Arnold J. Lehman, Director of the Division of Pharmacology, have from time to time participated in conferences with Army representatives concerned with the program and have been consulted with regard to certain technical phases of the program. Primarily Drs. Nelson and Lehman and their associates have been consulted with respect to the design of long-term animal feeding experiments and other procedures for evaluating factors of safety.

The Department of Health, Education, and Welfare has been actively represented on the Interdepartmental Commitee on Radiation Preservation of Food since the formation of that Committee. The special assistant to the Secretary for Health and Medical Affairs has been the departmental representative on the Committee. This was Dr. Winchell Craig, until his death on February 12, 1960. The Commissioner of Food and Drugs, George P. Larrick, has been the alternate Department representative on the Committee since its inception. Several of the scientists of the Food and Drug Administration and of the Public Health Service, and a representative of the Office of Education have served on technical points of contact groups under the Interdepartmental Committee.

While this Department is not in position to engage in activities leading to the development of processes or products, it does have responsibilities for developing and carrying out programs for the protection of the public health and for administration of the Federal Food, Drug, and Cosmetic Act. Various applications of atomic energy to industrial processes and products involve possible public health problems. Certainly the application of radiation to the preservation of food is of direct concern to this Department under its responsibilities for the administration of the Food, Drug, and Cosmetic Act and also because of its

52249 O—60—pt. 1——9

responsibilities in the general area of environmental health. The recent food additives amendment to the Food, Drug, and Cosmetic Act covers as a food additive any source of radiation intended for radiation treatment of foods, and it deems intentionaly irradiated food to be adulterated unless such use of radiation has been cleared for safety by regulation, or unless an exemption has been granted for research purposes.

Early last year representatives of the Office of Research and Development of the Department of the Army made inquiry of the Food and Drug Administration as to its attitude and legal responsibilities with respect to irradiation treatment of foods under the investigational program then being pursued under the leadership of the Army. This was discussed in some detail in a letter dated May 14, 1959, addressed to Col. Richard N. Oliver, Chief of the Office of Research and Development by the Deputy Commissioner of Food and Drugs. This letter is quoted in full:

MAY 14, 1959.

DEAR COLONEL OLIVER: Mr. Goodrich, our Assistant General Counsel, has told me of his meeting with you as well as his telephone conversations with you. As I understand it, you want an expression from us as to our attitude and legal responsibilities with respect to the irradiation treatment of foods under the investigational plan now being pursued under the leadership of the Department of the Army.

So long as the Army's treatment of foods is for the purpose of supplying military troops, it has always been our policy to allow the Army to make and follow its own rules which would protect the health of the service personnel. It will not be our disposition to sample any foods or to attempt regulatory action against any foods treated in the Army's program of supplying service personnel, so long as your scientific advisers tell you no health hazard exists.

If you feel that you would like some official assurance from us that the investigational plan which you proposed can be pursued, we will be glad to consider the issuance of regulations to provide exemptions for these foods for investigational use. Before we could issue such regulations under section 408(i) of the Federal Food, Drug, and Cosmetic Act, as amended by the food additives amendment in 1958, we would have to have a factual statement in writing from you showing the scope and content of the investigational plan, the use to be made of the treated foods, and the identity of the qualified experts who would be involved in the investigational program. We would also have to be assured that your exemption would be consistent with the public health. This would require adequate data to establish the identity and level of activity of every isotope produced in the treated food—whether from the food itself or from the package in which it is treated—as a result of the irradiation process. Ideally there should be a showing that the treated foods contain no added radioactivity whatever. Our advisers understand that it is possible to treat some foods with radioactive materials to sterilize them without leaving residues or byproducts from the treatment.

Mr. Goodrich's memorandum of the interview with you shows that your program contemplates residues of added radioactive material which would, however, be at or below the natural level of radioactivity for the particular foods treated. There would nevertheless be added radioactivity.

When it comes to phasing this development into the civilian economy, an entirely different problem arises. We have been specifically directed by the Congress to approve no additive "if it is found to induce cancer when ingested by man or animal." This precludes us from issuing a regulation which would authorize any residues of radioactive material in treated foods. If the facts are as we understand them, that the radioactive residues are carcinogenic substances, the fact that they may be present at levels which some experts would regard as entirely safe is no answer to the problem in light of the congressional prohibition against any amount whatever of cancer-producing materials.

Thus you see, it is possible for you to continue the investigational program, either on the Army's own responsibility or possibly under regulations providing for the investigational use. If this investigation should confirm the thought that radioactive treatment of foodstuffs is useful and should be made available to the general population, we see no alternative but to submit the problem to the Congress for a determination whether the prohibition imposed upon us can be relaxed.

I hope this will supply your needs for a statement of our position in your briefing of Dr. Martin next Monday.

JOHN L. HARVEY,
Deputy Commissioner.

In connection with the above-quoted letter, it should be noted that, since the issuance of that letter, the Secretary has reviewed the general question of the appropriateness of the anticancer clause in the food additives amendment of 1958 and, on the basis of scientific advice from the Public Health Service and the Food and Drug Administration, as well as a report of the Subcommittee on Carcinogenesis of the Food Protection Committee of the National Research Council, has concluded that in the present state of scientific knowledge no one can today determine what would be a safe tolerance for carcinogenic additives in food consumed by humans, and that therefore the principle of the anticancer proviso is sound to the extent that it applies to residues of carcinogenic additives in food intended for human consumption. Hence, in his testimony on January 26, 1960, before the House Committee on Interstate and Foreign Commerce on two color additive bills (S. 2197 and H.R. 7624), he took the position that he would favor modification of the anticancer proviso only for additives used in animal feed, where the additive will not adversely affect the animal and will leave no residue in any food product obtained from the animal.

In a letter of October 2, 1959, addressed to Mr. H. B. McCoy, Chairman of the Interdepartmental Committee, this Department suggested that it would be profitable for the Committee to appoint a task group to explore certain questions relative to the evaluation of the safety of irradiated food. It was suggested that to make such an evaluation the following facts for each foodstuff and for each method of radiation proposed for it would have to be known.

1. What the foodstuff is.
2. How it is packaged.
3. The kind and level of radioactivity to be applied to it, including all details of the process.
4. What effect the treatment has on wholesomeness, including its effect on certain enzyma systems and the biochemical changes produced.
5. Whether any carcinogenic materials are produced.
6. Whether any radioactive isotope is produced in the food, either from the food itself or from the package in which it is treated.
7. If the irradiation produces a substance not generally recognized by qualified experts as safe (i.e., a food additive), what practicable method is there for determining the quantity of this additive and any substance formed because of its use.

This Department is represented on the ad hoc working group recently established to review the situation and formulate a recommendation for the future activities of the Interdepartmental Committee on Radiation Preservation of Food.

CONSUMERS PUBLIC POWER DISTRICT,
Lincoln, Nebr., January 22, 1960.

Hon. CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy
Capitol Building, Washington, D.C.

DEAR SENATOR ANDERSON: Recent news reports indicate the Joint Committee's interest in reviewing the food irradiation program. Because the sodium graphite reactor has some unique design features which could complement an irradiation center, our organization became interested in the subject in 1955. For your information I am enclosing a résumé of the capabilities of this system.

Consumers District feels that a continuing aggressive program of development of irradiation should be carried on by its Atomic Energy Commission. Changes in reactor design and construction necessary for the irradiation facility have been made, and we continue to be keenly interested in the possibilities of irradiation at the Hallam plant.

Please let me know if you have any questions concerning the résumé, or if you would like to discuss the subject in more detail.

Sincerely,

EMERSON JONES,
Special Assistant to the General Manager.

Hallam Nuclear Power Facility and Its Relationship to the Food Irradiation Program

Consumers Public Power District first became interested in the field of radiation applications at the time our proposal was being prepared for the construction of a power reactor. This proposal was submitted to the Atomic Energy Commission early in 1955, and covered the construction and operation of a sodium graphite reactor capable of producing 75,000 kilowatts of electricity.

The proposal was accepted by the AEC in the so-called first round of the power reactor demonstration program. At the present time, the power station is under construction with full power reactor operation scheduled for early 1962.

The original proposal submitted to the AEC set out the potential value of using reactor sodium as a commercial source of radiation for a major radiation processing industry. This statement was based on the assumption that if industry develops continuous radiation processing as a production method, the shielding and handling equipment costs of a radiation facility would be essentially the same regardless of the radiation source. The choice of equipment, whether radionuclide or accelerator produced radiation, would then be expected to hinge on the cost of purchasing, installing, and operating only the radiation source.

For a sodium graphite power reactor, the sodium 24 is produced as a complete byproduct of the power production facility and the only incremental cost required to establish a multimegacurie source of radiation would arise from the installation and operation of a radiation plaque, connecting sodium pumps and lines and added sodium inventory. For this reason it appeared likely that the Hallam nuclear power facility could become a low cost radiation source. This approach continues to hold promise for the most economical sources of radiation.

In January of 1959, Atomics International as a reactor design organization, published the results of an AEC sponsored study on a radiation facility design which would meet the requirements of the food processing industry peculiar to the Hallam, Nebr., area. Atomics International is also the Hallam reactor design organization and could therefore consider the inter-relationship of the two designs and assure the safety and operability of the entire installation.

The source strength of the facility described uses primary system sodium from the Hallam reactor and is calculated to be 2.11×10^5 rep/hr. This gamma-ray dose level results from a source density of 0.325 c/cm^3 in the primary system sodium. Total sodium 24 activity in the facility is approximately 3.5×10^6c.

The Atomics International study shows the facility has a capacity to process an estimated 523 tons per day of a variety of materials to a total integrated dose of 10^5 rep. Higher exposures are feasible with a corresponding reduction in throughput. The design developed as a result of this study comprises four different types of conveyor systems to provide flexibility for handling different types of process materials through the five-plaque call. If process material involving standardized package configurations were to be processed through the facility, it is estimated that, by sacrificing flexibility, the capacity could be increased to approximately 800 tons per day at the same 10^5 rep dose level.

Natural sodium consists of the single isotope, sodium 23, which upon neutron absorption, is transformed into the radioactive isotope, sodium 24. The half life of sodium 24 is 15.06 hours. The isotope emits two gamma rays of 1.38 mav and 2.76 mav in essentially 100 percent of its disintegrations.

The specific activity of the sodium coolant is a direct function of the reactor power level and is determined also by the degree of dilution which is imposed on the coolant during its passage through the core and into the facility radiator system. The specific activity of 0.325 c/cm^3 is based on reactor coolant which has been diluted by the total 7,100-foot^3 volume of the HNPF primary coolant system. Sudden changes in reactor power will produce slow changes in sodium activity because of the relatively long 15-hour half life.

The efficiency in utilizing this radiation source is a secondary consideration in view of the fact that the sodium 24 is produced as a complete byproduct of the power reactor operation. As a result, greater attention may be devoted to a source configuration which will lead to minimum construction, operation and maintenance costs, with greater safety and uniformity of exposure.

For uncollimated gamma ray sources, which produce radiation in all directions, an arrangement of a slab geometry was selected as the best configuration for the design. Exposure rate variations across the face of slab would be less severe than with other configurations considered. Preliminary calculations indicate that the gamma ray dose rate from a spiral slab radiator would be lower than the exposure level obtained from an equivalent rectangular fabrica-

tion and the simplicity of cell component arrangement also would indicate that a rectangular slab type of source configuration is more desirable.

The Hallam nuclear power facility reactor is designed to operate with a minimum of two of the three primary coolant loops. In order to assure a continuous sodium supply, outlets for sodium for the radiation plaques are being made in two of these loops. The sodium is taken from the "cold" side of the heat exchanger, where the design temperature of the sodium is 607° F. The fluid is circulated, by means of a 3-inch electromagnetic pump, through the five plaques and returned to the same primary coolant loop. The flow of 100 gallons per minute through the system is negligible, compared to the flow in the primary loop of the Hallam facility. At this flow rate, the sodium is changed in each of the five plaques every 28 minutes. Since sodium 24 loses 5 percent of its activity at the end of the first hour, there will not be any appreciable change in the activity of the sodium in the plaques. At a flow rate of 100 gallons per minute, the pressure drop in the system is about 5 pounds per square inch. The temperature of the sodium is expected to drop less than 25° F. from the point it is taken from the Hallam facility to the point of its return to the reactor coolant loop. The effect on the powerplant system is almost negligible.

In the event that personnel need to enter the radiation chamber, the sodium is drained from the plaques and replaced with helium. To remove entrained radioactive sodium from the plaque cells, the system can be flushed with fresh sodium from the primary fill tanks of the Hallam facility. In this procedure, the reserve coolant of the reactor coolant storage system would be used. This "on-off" capability combines one of the advantages of machine radiation with the greater penetration available from radionuclides.

The design developed in the study consisted of five conveyors moving horizontally between the irradiation plaques. One conveyor is a special tray type, capable of carrying bags, boxes, or cans. Two conveyors are of the basket type, to carry No. 10 or No. 2 cans, packages, and V–3 or smaller size boxes. One conveyer is a flat chain type and the last system handles bulk granular materials. Each conveyor is equipped with an independent drive. All conveyors can be operated simultaneously, each being irradiated to a different dose.

The conveying system has not been designed to meet a specific workload. Instead, it is a flexible system, that can irradiate a large number of different types and sizes of materials, to dosages between the range of 10^4 and 3×10^6 rep. A more efficient conveying system could be designed to meet a definite market requirement consisting of a limited number of products and package configurations.

From the conveyor terminal area above ground, the packaged material is transported down the inclined tunnel, around a labyrinth-type shield, and in and out between the five radiation plaques in the irradiation chamber. It is then returned through the labyrinth, and up the inclined tunnel to the conveyor terminal zone. The total length of each conveyor is approximately 380 feet, of which 140 feet is inside the irradiation chamber. Steel guides along the conveyor route are designed to prevent misalinement of packages.

Some loss and degradation of material in the conveyors is expected due mainly to mishandling. Degradation will occur, especially for materials passing through the screw conveyor.

The special tray-type conveyor is basically a trolley conveyor. It can carry up to 100-pound potato bags, or packages spaced 2 feet between centers. For an integrated dose of 10^6 rep, the capacity of this conveyor is 16,800 pounds per hour. For this dose, the speed of the conveyor would be about 5 feet per minute. Assuming potatoes are being irradiated, the generally accepted dose to inhibit sprouting is 2×10^4 rep. The capacity of the conveyor for this dose would be 84,000 pounds per hour, or 840 100-pound bags an hour. This rate is higher than can be handled by the available manpower.

The speed of the special tray-type conveyor can be varied from 0 to 75 feet per minute. At 0.1 feet per minute, the material will be irradiated to more than 6×10^6 rep. The material will be in the conveyor for more than 63 hours. Of this time, about 23 hours will be spent in the irradiation chamber. At a speed of 75 feet per minute, the integrated irradiation dose is calculated to be 7,000 rep. The conveyor will pass through the irradiation chamber in less than 2 minutes, and the total time in the conveyor would be about 5 minutes.

The two smaller basket-type trolley conveyors are identical. They are designed to carry packages, boxes, or cans spaced 18 inches between centers. The maximum size box that can be carried is 6 inches by 16 inches by 21 inches.

The V–3 size boxes fall in this category. The capacity of each of these conveyors, loaded with V–3 boxes for a dose of 10^5 rep, is 15,200 pounds per hour, moving at a speed of about 5 feet per minute. The two conveyors, although identical, are completely independent of each other. Each has a speed range from 0 to 75 feet per minute. The speeds of the conveyors and the time spent inside the irradiation chamber are the same as for the special tray-type conveyor.

The flat chain conveyor is similar to a flat belt conveyor but is capable of following horizontal curves. It is 7 inches wide, and can carry boxes or cans of various dimensions, including orange crates. Assuming that it is loaded at 25 pounds per foot, the capacity at 10^5 rep dose is 7,600 pounds per hour. The speeds of the conveyor and the time inside the irradiation chamber for a given dose is the same as for the trolley conveyors.

The screw conveyor is for bulk material which is dumped into a hopper directly over the irradiation cell. The material flows through a chute into two sets of screw-type conveyors, installed horizontally between radiation plaques. These conveyors move the material slowly from one end of the radiation plaques to the other and back again. The material is then discharged into an elevator conveyor in the gallery below floor level, which raises it above ground for reloading. The chute is 10 inches in diameter. The screw conveyor is 14 inches in diameter and has a 14-inch pitch. The conveyor elevator is 10¾ inches by 6½ inches. To minimize maintenance, the return leg of the conveyor elevator is separated from the incoming leg.

Assuming that wheat is being irradiated to 10^5 rep, the capacity of the bulk type conveyor is 3,350 pounds per hour. However, for deinfestation, only 2.5×10^4 rep appears necessary. For that dose, the capacity of the conveyor is 6.7 tons per hour, and the speed of the screw conveyor would be about 5 feet per minute. The speed range of this conveyor is 0.5 to 15 feet per minute, which would provide a dose from 8×10^3 to 2.5×10^5 rep.

The cost estimate for the facility, without any warehousing or associated buildings and equipment, is approximately $1 million. For the retirement of the debt on the equipment previously described and for the operation of that equipment, the processing costs should be approximately one-tenth of a cent per pound for exposure of 10^5 r.e.p. This assumes 15 percent fixed charges on the investment and plant operation during 75 percent of the available time. This results in a throughput rate of 523 tons per day.

The main line of a major east-west railroad passes along one side of the site, and results in transit privileges for commodities being delayed for radiation processing at the site. Depending upon the product involved, this cost would result in no increase up to an additional one-tenth of a cent per pound for a plant having the capacity described in this report.

Current research efforts indicate that the first most likely application for foodstuffs will be pasteurization (10^5 r.e.p.). This process, when combined with existing refrigeration methods, will result in increased storage life of from 2 to 10 times, depending upon the product. Somewhat lower dosages are completely adequate for deinfestation of grains. These applications could be put into practice immediately, without incurring the difficulties of color and taste changes associated with the higher exposures required for sterilization.

Throughout the development of this program it has been our opinion that this source of radiation, located in the center of the food producing area of the United States, should be among the first of the commercially feasible radiation facilities. In addition, it has the capacity to contribute to this Nation's demonstration of the technology and economics of the radiation program. It would also seem true that these same considerations would be of interest to those foreign countries which are dependent upon grain as a primary ingredient in their national diet.

For these reasons, we feel this reactor installation can lend a new meaning to the concept of a dual purpose system; that is, power production and an economic source of radiation. Our organization is primarily interested in the production of power, and it is the stated policy of Consumers Public Power District to cooperate fully with the Nebraska Resources Division (a division of State government) in order to develop this new industry.

A portion of Consumers' board of directors statement policy reads as follows: "Consumers' staff will provide byproduct, technical, economic, and other information to the Nebraska Resources Division in order that the division can most effectively continue to develop industrial and agricultural interest in the use of the plant's radiation sources. It is anticipated that inquiries from

organizations planning to utilize the irradiation facilities will be directed to the Nebraska Resources Division.

"When individual organizations develop preliminary proposals for utilization of the byproducts, Consumers District will then negotiate with them to establish compatibility with the electric power operation and Atomic Energy Commission regulations, and develop contracts for the byproducts. In order to assist this development, charges set by the Consumers District for the byproduct will be as low as possible, and yet consistent with its larger objective, i.e., providing electric service to its 120,000 electric customers at costs comparable to that of energy produced by conventional methods of power generation."

With the Hallam nuclear power facility located 20 miles from the University of Nebraska Agricultural College, the technical equipment and personnel necessary for a food evaluation program could be available for a food irradiation program. This program could represent a minimum cost approach to a study of civilian food irradiation problems rather than the specialized and frequently conflicting requirements of military food programs.

(Whereupon, at 11:55 a.m. the committee was recessed, to reconvene subject to call of the Chair.)

APPENDIXES

APPENDIX 1

OFFICE OF THE SECRETARY OF DEFENSE,
February 18, 1960.

Hon. CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy,
Congress of the United States.

DEAR MR. CHAIRMAN: Attached is ad hoc panel report to the Interdepartmental Committee on Radiation Preservation of Foods on a National Civilian Radiation Processed Foods Program, which will be of interest to your committee.

I will inform you of action taken by the Interdepartmental Committee on the report when the action is finalized.

Sincerely yours,

HERBERT B. LOPER,
Assistant to the Secretary of Defense (Atomic Energy).

February 25, 1960.

Mr. JOHN T. CONWAY,
Assistant Director, Joint Committee on Atomic Energy, Congress of the United States.

DEAR MR. CONWAY: In accordance with your request, via the AEC Office of Congressional Liaison, I am enclosing 25 copies of the ad hoc panel report which was adopted on February 12 by the Interdepartmental Committee on Radiation Preservation of Food with two recommendation changes as noted on page 4.

Sincerely yours,

PAUL C. AEBERSOLD,
Chairman, Ad Hoc Panel.

AD HOC PANEL REPORT TO THE INTERDEPARTMENTAL COMMITTEE ON RADIATION PRESERVATION OF FOODS ON A NATIONAL CIVILIAN RADIATION PROCESSED FOODS PROGRAM

PREFACE

At a meeting on November 24, 1959, the Interdepartmental Committee on Radiation Preservation of Food agreed to establish an ad hoc panel to formulate a national civilian radiation processed foods program. This was prompted primarily by the Department of the Army decision to reorient its program more toward research and to concentrate on radiation sterilization of a few items of military interest. It was therefore deemed necessary to consider a complementary program to implement civilian interest in radiation processed foods.

In appointing members of the ad hoc panel, Mr. H. B. McCoy, then Chairman of the Interdepartmental Committee, defined its task as follows:

1. Make an assessment of the current "state of the art."
2. Review progress achieved in Government activities.
3. Consider what problems or issues now need to be dealt with to advance the radiation processing of food.
4. List specific areas of further research and development.
5. Recommend how and in what way the future program in the Government may be administered.
6. Make suggestions and recommendations regarding size of the research and development program.
7. Indicate what, if anything, the Federal Government might do to encourage research and development by private firms, institutions, etc.

The following report has been concurred in by all members of the ad hoc panel, with the exception of Dale H. Sieling and David H. Rest. They desire that references in the report to cobalt 60 and X-ray machines be accompanied by mention of electron accelerators as alternate on additional radiation sources. This matter should be considered at the meeting of the Interdepartmental Committee.

This report does not spell out in detail the technical elements of the proposed program. This would be one of the first program activities. Furthermore, the report does not embody a comprehensive analysis of the current state of technology of radiation-processed foods but rather broadly identifies technical prospects for foods processed at sterilization and pasteurization doses. It is to be noted also that the program has been developed without benefit of detailed knowledge of future Army plans.

This report is concerned only with conduct of research and development on radiation processing of foods. It does not attempt to define individual Government agency responsibilities in such areas as regulation, health and safety, etc., and does not imply any commitment by any Government agency with respect to any regulatory matter within its jurisdiction.

MEMBERSHIP

Paul C. Aebersold, Chairman	Atomic Energy Commission.
John Holston	Department of the Interior.
H. W. Koch	Department of Commerce.
Jacob M. Schaffer	Do.
Samuel N. Klein	Small Business Administration.
David H. Rest	Quartermaster Food and Container Institute for the Armed Forces.
Col. Lawrence Hursh	Office of the Surgeon General.
Wilbur T. Pentzer	Department of Agriculture.
Andrew Wheeler	Health, Education, and Welfare.
Shelbey Grey	Do.

RECOMMENDATIONS

It is recommended that—

1. The Interdepartmental Committee approve the national civilian radiation processed foods program as set forth in part B of the report and refer it to member agencies for concurrence and implementation.

2. The Atomic Energy Commission be designated as the operating agency for the national civilian radiation processed foods program.

3. The Interdepartmental Committee support the need for a complementary program by the Department of the Army on radiation preservation of foods and the requirement to pursue such a program aggressively.

4. The Army complete its wholesomeness and safety program at sterilization doses to resolve biological anomalies that have arisen from long-term feeding studies and that AEC assist in this program as mutually agreed upon, as well an initiate a wholesomeness program on selected foods at substerilization doses.[1]

5. A wholesomeness program working panel to the Interdepartmental Committee be established consisting of the Army, AEC, FDA, Department of Agriculture, and consultants as required to coordinate this program.[1]

6. The Interdepartmental Committee support the requirement by the Department of the Army for adequate food preparation and radiation facilities to carry out effectively its research and development program.

7. Radiation research facilities established for either the Department of the Army program or the civilian radiation processed foods program be mutually accessible.

---

[1] These recommendations were added at the meeting of the Interdepartmental Committee held on Feb. 12, 1960, and were not a part of the report to the Committee by the ad hoc panel.

8. Close liaison be established between the Department of the Army and the operating agency for the civilian radiation processed foods program on technical and administrative matters, including budgets and scope of program activities.

INTRODUCTION

To understand the objectives and problems of food preservation by radiation, it is necessary to appreciate what causes food to deteriorate. Food deteriorates in many ways: Through physical, chemical, and enzymatic changes, and by activity of micro-organisms and insects. Chemical and enzyme deterioration are only minutely affected by low doses of radiation contemplated for food processing, and physical changes, such as softening, may be promoted. The most promising areas for applications of low-dose radiation are in control of insects and of microbiological damage.

Chemical spoilage of foods results from food components reacting with their environment or with other food components; for example, the reaction of fats with oxygen in air to cause rancidity. Radiation does no more or less to retard these reactions than does any other method of food preservation. These reactions are controlled to various degrees, however, with appropriate food technology.

Enzymatic spoilage results from enzymes in foods reacting with the food itself, i.e., "self-digestion." Neither freezing nor irradiating stops this reaction although these processes may retard the reaction. Heat inactivates enzymes; hence, thermal processing does stop this reaction. In freezing, drying, or radiation preservation, a blanching or low heat treatment can be used to inactivate the enzymes during preservation.

Spoilage may result from the action of both insects and micro-organisms. Ionizing radiation can destroy or inhibit these agents. This is the purpose of radiation processing.

Fresh untreated foods are generally subject to spoilage by all the mechanisms mentioned. Physical, chemical, and enzymatic changes are of major concern in long-term storage, and they can be retarded by refrigeration. Spoilage by these mechanisms is generally not important during storage periods less than a month or two especially if adequate refrigeration is used. On the other hand, spoilage by micro-organisms is often the prime cause of the rapid deterioration of perishable foods, and while refrigeration is helpful, it often will not do the job alone. Thus, the use of radiation to control microbiological spoilage and extend refrigerated shelf life of freshlife products becomes a most important goal. Radiation is also a potent means of killing insects that damage foods.

Micro-organisms and insects can be destroyed or their destructive action reduced by the use of irradiation, often with fewer deleterious effects on the product than caused by other methods. That is, a fresh or freshlike product can, in some instances, be stored considerably longer than it now possible. For example, some fish and shellfish can be treated with ionizing radiation so that the fresh product can be stored under refrigeration (not frozen) for weeks instead of days.

With regard to shellfish, it is worth noting that prepared, cooked, shimp sterilized by irradiation can be stored at room temperature for many months and then be essentially undistinguishable from prepared, cooked, fresh shrimp. Other types of commodities can be so treated. In addition, successful results have been experienced in extending the refrigerated shelf life of chicken, fish, pork, beef, grapes, strawberries, and citrus fruit irradiated at substerilization doses.

Much need exists for improved food preservation to make wider distribution from products and food surplus areas. The recent International Conference on Preservation of Foods by Ionizing Radiations held at the Massachusetts Institute of Technology [2] clearly demonstrates the worldwide interest in radiation

[2] Report available from the Office of Technical Services, U.S. Department of Commerce, Washington, D.C.

processing of food and the faith that the United States will continue to be a leader in this development.

Domestically, any method that can increase the storage, distribution, and utility of our food resources will be of great economic advantage. For example, wide distribution of fresh ocean products in the Midwest can mean added prosperity to the fish industry. The same is true about supplying strawberries, peaches, and tropical and citrus fruits to distant markets.

In the last 5 years, the U.S. Department of the Army has carried on an extensive program to develop radiation preservation of food mainly for military purposes. Military food needs, however, are not the same as the food needs for civilian distribution. The need to store food for extended periods under adverse conditions, to distribute food to widely dispersed fighting units, to feed under conditions of great stress, all give rise to a military feeding system that has no parallel in the civilian population. Military requirements for irradiated foods will thus not necessarily be compatible with the needs of irradiated foods in the civilian feeding system.

The military requires a sterile, ready-to-eat food of high-nutritional density that will be acceptable and morale building to the fighting man even after repetitive feedings. This resolves itself in the irradiated food field to completely sterilized meat products which comprise large tonnages of military subsistence, such as, beef, pork, ham, and chicken. It is then reasonable to expect that the Army concentrate its efforts on developing these items.

The civilian needs on the other hand stem from the problem of distributing and utilizing foods in as near fresh condition as possible. At one time dried and salted foods were the closest to fresh foods that could be preserved and distributed. Subsequently, pickling and curing processes replaced some but not all of the drying and salting operations. The situation has been similar following the development of thermal processing, freezing, and improved dehydration processes. Each process has developed very useful roles. So it may be with radiation processing. Some food items will yield outstanding products by irradiation. But the process will not be universally applicable. The amounts of dried, smoked, pickled, canned, and frozen food items will not be greatly affected.

Sterility may be obtained by combining other treatments such as heat or antibiotics with radiation. In this case the irradiation dose can be considerably reduced thus minimizing the development of off-flavor or other undesirable effects. At the same time, beneficial effects can be obtained such as flavor and texture improvement by reducing the amount of heat needed to sterilize canned meats by combining heat with irradiation. This can be of interest for both Army and civilian needs.

While the fundamental problems in the development of both a moderately treated food and a completely sterilized food with radiation are the same, there are specific differences that require separate investigations. For example, the microbiology of completely sterile foods involve the killing of the *Clostridium botulinum* (botulinus) organism, requiring very high dosages. The microbiology of pasteurizing strawberries depends upon interference with the metabolism of rhizopus, requiring much lower dosage. Also, the packaging of sterile foods must be sealed hermetically, whereas for pasteurized fruits, the package must allow for respiration.

Much evidence has thus been accumulated to show that a need exists to develop moderate dose radiation processing of foods to the point of commercial feasibility.

The foregoing has adequately shown that there is justification for both military and civilian programs for radiation processing of foods. The Army program would continue to concentrate on development of combat-ration components for long-term storage and the national civilian program should seek moderate shelf-life extensions to produce foods of greater commercial utility.

These programs can be complementary and mutually beneficial in some areas but would be widely divergent in others. Fundamental research, dosimetry studies, wholesomeness, and radiation source technology are among those items which can be shared by both the military and civilian programs. Requirements of the two programs in such matters as microbiology, product development, process engineering, and packaging will be vastly different.

An important example where the two program requirements could overlap would be in the use of a national radiation processing of foods center. The requirements and plans for a national center are detailed in attachment I to part B of this report.

A summary of the current status of the technology of radiation processing of foods is given in part A of this report, and a recommended national civilian radiation processed foods program is contained in part B.

PART A. CURRENT STATUS OF THE TECHNOLOGY OF RADIATION PROCESSING OF FOODS

I. INTRODUCTION

Research on the radiation processing of foods commenced over 10 years ago. Within the past 6 years a full-scale development program has been concentrated in the United States on this new concept in food technology. Work on radiation processed foods in other countries has also been initiated and is being pursued actively. Major effort in the United States has been supported by the Government, primarily the Department of Defense, through contractual research projects at universities, research institutes, and private companies. Current selected information on radiation-processed foods technology can be found in the previously mentioned report on the MIT International Conference on the Preservation of Foods by Ionizing Radiation. A comprehensive survey of the field through 1957 is contained in the U.S. Army Quartermaster Corps publication entitled, "Radiation Preservation of Food."[3] However, the rate of accumulation of information in this subject area has increased sharply since the latter book was published. Therefore, it is necessary to consult the recent scientific journals for the most important new information.

II. RESULTS FROM EXPERIMENTAL INVESTIGATIONS

The comprehensive research and development program on radiation processing of food has revealed some products having potential for commercialization. Radiation sterilization of some meats, such as beef, still poses major problems but other items, such as chicken, fish, and pork products, show promise as completely sterile products. Generally, however, substerilization offers more immediate promise since effects on quality (flavor, texture, and color) are minimized and the processing costs more nearly approach those of conventional processing methods. The substerilization of marine products, chicken, and some selected fruit products, such as strawberries, to extend shelf-life appears promising.

III. PRESENT PRODUCT STATUS

A. Meats

1. *Beef.*—Radiation sterilized beef frequently has an off-flavor. The U.S. Army is intensively investigating the formation of off-flavor in beef and methods to overcome it as sterilized beef is a prime objective of the Army. Modest doses of radiation can be used to delay microbial spoilage of cuts of beef stored at 35° F., thus extending shelf life from about 5 days to perhaps 6 weeks.

2. *Chicken.*—Sterilizing doses produced minimal changes in taste and odor. Radiation sterilized chicken is slightly more pink in appearance than unirradiated chicken. Chicken irradiated with substerilization doses and held at 35° F., has its shelf life extended to 30 days or more compared with 10 days for untreated chicken and retains acceptable taste and odor.

3. *Pork.*—(*a*) Roast pork: Experiments conducted by the Army demonstrated that preheated or roasted pork that is subsequently radiation sterilized is better in quality than heat-processed canned pork. The texture and flavor of radiation processed brown-and-serve pork is highly acceptable.

(*b*) Sausage: The flavor of some formulations of pork sausage is little affected by radiation processing. Shelf life of sausages given 1 megarad and held at 35° F., is more than 6 weeks compared with 2 weeks for control sausages.

(*c*) Bacon: The Army has reported good results on bacon with respect to acceptability at sterilization doses.

B. Marine products

Fishery products are promising for commercial radiation processing. Fourfold increases in refrigerated shelf life after substerilization doses are found. The radiation processing of fish and shellfish, such as halibut, acean perch, cod, shrimp, crab meat, and lobster are perhaps the most promising for commercial-

[3] Available as Report No. PB 151493 from the Office of Technical Services, U.S. Department of Commerce, Washington, D.C., price $5.

ization, since the flavor, odor, color, and texture of these radiation-processed products are likely to meet with consumer acceptance. Many fishery products are quite perishable and a fourfold increase in shelf life under refrigeration would be of significant benefit to the consumer and to the fishing industry.

C. Vegetables

Sterilization of fresh vegetables has not been developed. Fair results have been obtained with substerilization treatment of several vegetables, such as carrots and asparagus. The spoilage of vegetables, such as asparagus, due to rot and fungi may be controlled with substerilization doses.

D. Fruits

Substerilization processing of fruits, such as strawberries, citrus fruits, grapes, and peaches, may offer promise for commercialization. The low-dose treatment of these fruit items can control spoilage due to rhisopus, gray mold, and brown rot, respectively. Shelf life extension for transcontinental shipment of a high-spoilage item, such as strawberries, could be highly beneficial to the consumer and the grower. With respect to tropical fruits, such as payayas and mangoes, most serious problem of marketing is disinfestation of various fruitflies. It appears that low-dose treatment of fruits can solve this problem.

E. Grains

Radiation treatment has been investigated for the disinfestation of grain. Questions which have not been well answered in this regard include comparison between cost of chemical and radiation disinfestation, prevention of reinfestation, and the problem of multiple-radiation treatment, if required. Radiation disinfestation of grain or grain products may find commercial applications.

F. Sprout inhibition

Prevention of sprouting in tubers, particularly potatoes, as a result of radiation treatment has been amply demonstrated. Radiation treatment makes it possible to inhibit sprouting for long periods under commercial conditions. There are problems to be overcome in subsequent decay prevention.

IV. WHOLESOMENESS AND SAFETY CLEARANCE

A most comprehensive program to test the nutritional and toxicological safety of irradiated food has been conducted by the Department of the Army (Office of the Surgeon General). This program exceeds any animal feeding program that has ever been conducted on processed foods. The plans for the tests have been developed in close liaison with the Food and Drug Administration. It is our understanding that 3 to 5 more years would be required to complete and analyze feeding studies. Research in this area is intended to determine whether irradiated foods are safe and wholesome.

Much concern developed recently on the problem of induced radioactivity when it was observed that short-lived radioactive isotopes with low activity could be measured in foods treated with high energy electrons. Fortunately, however, experimental evidence indicates that low energy gamma sources such as cobalt 60 and cesium 137, or X-rays of comparable low energy, as would be expected, do not produce detectable activity in foods. The Food and Drug Administration will of course require documentary evidence on the safety of these sources for food processing.

V. PACKAGING

Experimental studies to date have been directed largely at satisfactory packaging materials for sterilization processing. Considerable work remains to be done in studying satisfactory packaging materials for substerilization processing. Such containers must not only be capable of preventing microbial recontamination, but also of permitting transmission of respiratory gases. In addition, it must be determined what types of chemical byproducts result from the packaging material since minute amounts of extractable substances produced during irradiation could result in undesirable effects in the food.

VI. RADIATION FACILITIES

Radiation sources currently used for the radiation processing of foods program are generally inadequate in size and characteristics, and are usually located at distances from both the source of food supply and the research laboratory.

The principal existing gamma sources consist of reactor fuel elements of various types used under dissimilar conditions of exposure at sites far removed from food-processing laboratories. Progress is being limited by the need for additional gamma irradiators or low energy X-ray machines to develop the best and most economic conditions for radiation processing of a wide variety of food products.

VII. ECONOMICS

Economics of radiation processing are presently based on laboratory studies and calculations rather than on experience under pilot plant conditions. Cost estimates for sterilization treatment have been on the order of a few cents per pound whereas the estimated cost for substerilization processing has generally been on the order of a few tenths of a cent per pound. Reliable cost information will not become available until quasi-commercial plants are built.

Part B. Recommended National Civilian Radiation Processed Foods Program

I. PROGRAM DESCRIPTION

To conduct research and development, economic, marketing, and consumer acceptance studies, and feasibility demonstrations during the next 5 years necessary to establish the commercial practicality of civilian applications of radiation processed foods that would accelerate their introduction into the economy. The immediate objective would be to concentrate on a small number of selected food products which appear to promise early technical feasibility and market acceptance.

II. BASIC ASSUMPTIONS

A. The most immediate civilian application of radiation to preserve foods, both from a technical and economic point of view, is low dose treatment to extend shelf life of perishable foods, including meat, fish, vegetables, and fruits.

B. Establishing the wholesomeness and safety of radiation processed foods will for some years be largely a Government responsibility since industry would not undertake both high-capital costs for radiation processing plants and expensive long-term wholesomeness costs. Short-term wholesomeness tests could be expected of industry on individual items, having particular commercial attractiveness.

C. The Army wholesomeness and safety program at sterilizing and substerilizing doses will be completed and will contribute information toward clearance for these foods as well as additional foods irradiated to lower substerilization doses; however, a modest amount of supplemental work may be necessary to obtain clearance for foods of interest in the civilian program.

D. The provisions of Public Law 85–929, September 6, 1958, which amended the Federal Food, Drug, and Cosmetic Act, must be met as regards the use of radiation as a food additive. Since radioactivity under some circumstances is carcinogenic, radiation processing of food which will induce measurable radioactivity in the food will not be permitted under the present law.

E. Public acceptance of radiation processed foods must be demonstrated. Even though a number of food items may have been given FDA clearance by high-dose tests, animal and human volunteer feeding studies with specific low-dose treated foods may be required for psychological reasons.

F. Establishment of the commercial success of a few radiation processed foods will prompt industry to extend independently the technology throughout the broad spectrum of food products.

G. Individual Federal agencies will continue to conduct long-range fundamental research programs on radiation effects on food. The Army program will continue and will supply much fundamental data of this kind which would otherwise have to be developed under the civilian program.

III. PROGRAM ADMINISTRATION

A. The interdepartmental committee will provide overall guidance and recommendations in program policy, direction, and budget. It will function principally as a coordinating committee rather than an operating committee.

B. Program administration would be conducted by one designated agency on behalf of the interdepartmental committee and its member agencies. This is to include program budgeting, contracting, and reporting. It is proposed that AEC

be the operating agency because (1) much of the food process development work required involves radiation source technology and radiation engineering, and (2) the radiation processed foods program would be a principal facet of the Nation's atoms-for-peace program.

C. The interdepartmental committee would function by:

1. Reviewing and making recommendations concerning the overall program as presented annually by the operating agency, including the proposed budget request to Congress.

NOTE.—This would not preclude any agency pursuing activities with its own funds independently of the interdepartmental committee, and does not imply interdepartmental committee control of agency research and development program.

2. Receiving periodic reports and evaluations from the operating agency on the status of the program.

3. Meeting at least semiannually to consider policies, programs, and procedures and issue such public statements as may be considered desirable.

4. Establishing a program coordination committee of the most directly participating agencies to meet as necessary at the call of the operating agency to consider specific problems as they arise.

D. The operating agency will function by:

1. Preparing the overall program and budget for review and recommendation by the interdepartmental committee and making the budget request to Congress.

2. Consulting the member agencies on proposed programs and projects including cost and justifications, for inclusion in the overall program.

3. Receiving proposals from private organizations and reviewing them where necessary with an appropriate member agency.

4. Making agreements and contracting with member agencies and others for conduct of work.

5. Reviewing and evaluating reports, etc., from contractors and others with appropriate member agencies and other experts in the field as well as assuring the availability of such reports and evaluations to member agencies, industry, the public, and foreign countries as appropriate.

6. Establish and consult as necessary with a committee of the National Research Council on civilian radiation preservation of food regarding broad program policy and objectives.

IV. PROGRAM OBJECTIVES

A. To further the national atoms-for-peace and war-on-hunger programs, assume U.S. world leadership in the radiation processing of foods, and provide technical assistance in this field to developing countries.

B. To identify potential civilian applications of radiation-processed foods which would have substantial technical, economic, or other significance in food production, processing, distribution, marketing, or consumption.

C. For selected food products conduct research and development work necessary to establish the technical and commercial feasibility of radiation processing.

D. To supplement Army wholesomeness and safety studies as necessary to obtain FDA clearance for the above referenced selected food products and to conduct continuing wholesomeness studies on radiation-processed foods of interest in the civilian economy.

E. Through suitable Government and private facilities, and with adequate "promotions," to test market for these selected radiation-processed food products.

F. To conduct studies of basic nutritional and organoleptic factors on the biochemical level to compare radiation-processed foods with foods processed by other methods, specifically to compare fresh, frozen, and irradiated foods after typical consumer storage and cooking procedures.

V. COOPERATION WITH INDUSTRY

A policy of maximum cooperation with industry will be followed. Extensive use should be made of "radiation study agreements" in which for a given phase of work the Government supplies the service of irradiation of the food, and industry performs the remaining parts of the investigation. Results from the investigations are then made available to all those who are cooperating in the program.

In this way it is expected that industry will make most of its contributions in investigations in the areas of shelf life extension, packaging, consumer acceptability testing, and marketing analyses. The Government would be expected to support the major work in the areas of fundamental research, microbiology, food chemistry, and causes of organoleptic changes, etc., provide irradiation services, develop economic and safe radiation process technology, and conduct basic wholesomeness testing.

VI. FACILITY REQUIREMENTS

In view of the combined needs of the military and civilian programs, a national radiation-processed foods research and development center would materially accelerate progress. Certain specialized radiation facilities for food processing—e.g., research irradiators and mobile food irradiators—also will be necessary to achieve the foregoing program objective. Attachment 1 sets forth in detail proposed facilities for radiation-processed foods research and their estimated construction costs, as well as alternative facility recommendations, depending upon action on the Army program.

VII. PROBLEMS FORESEEN

A. Due to the budgeting cycle, it would not be expected adequate operating funds will be available for the civilian radiation-processed foods program before fiscal year 1962.

B. Assuming the Army arrives at a decision or other arrangements are made to proceed promptly with construction of a research and development radiation center for food processing, it would not be available for use before fiscal year 1962. If the center must await the customary budgeting process, it would not be available for use until fiscal year 1964. Thus 2 years can be saved if the center can be undertaken promptly.

VIII. INITIAL ACTIVITIES

A. Survey all research and development work to date to analyze and collect data relevant to the civilian program.

B. Conduct studies described in IV–B above.

C. In selected cases, identify scope and cost of research and development program needed and initiate preliminary experimental work.

D. Design mobile irradiators consisting of high-intensity cobalt 60 sources and/or X-ray sources of comparable energy.

E. Analyze status and timing of Army wholesomeness program and establish close and continuing liaison with this activity.

NOTE.—B and C above have already been done in the case of fish by MIT under contract with AEC. A full report will soon be available.

IX. BUDGET ESTIMATES

Assumptions

1. Eight food items to be developed.
2. Man-years charged at total cost of $25,000 each.
3. The estimates are made on the basis of cobalt 60 as the radiation source. It might be desirable to use low-energy electron accelerators as the radiation source for some of the irradiators envisioned. In this event, the cost estimate will be comparable to the cobalt 60 source estimate.

Operating costs

	Fiscal year 1960	Fiscal year 1961	Fiscal year 1962	Fiscal year 1963
Initial activities	$200,000			
Equipment:				
Research irradiators (4)	200,000			
Mobile irradiators (2)		$400,000		
Food chemistry		50,000	$200,000	$200,000
Microbiology		100,000	400,000	400,000
Product development		100,000	400,000	400,000
Nuclear effects		25,000	25,000	25,000
Process engineering			25,000	50,000
Packaging development		25,000	50,000	75,000
National center operation			50,000	150,000
Commodity procurement and shipping		10,000	35,000	50,000
Irradiation services		180,000	200,000	250,000
Supplementary wholesomeness		30,000	60,000	90,000
Total	400,000	920,000	1,445,000	1,690,000

Construction [1]

	Fiscal year 1960	Fiscal year 1961	Fiscal year 1962	Fiscal year 1963
National center			[2] $1,400,000	
Marine products irradiator			[3] 500,000	

[1] Alternative recommendations depending upon action on the Army program are set forth in attachment 1.

[2] Not required if Army funds presently held by AEC for a gamma facility are available to build a center to which civilian program has access. Assumes cobalt 60 at Army price.

[3] Not required if national center built in a suitable location either by Army as above, or by civilian program.

ATTACHMENT I

IRRADIATION FACILITIES FOR A NATIONAL CIVILIAN RADIATION PROCESSED FOODS PROGRAM

I. INTRODUCTION

Irradition facilities for the conduct of research and process development for a national civilian radiation processed foods program are discussed. The construction of several specialized facilities is proposed. These facilities would also be available for use by the Department of Defense, other Government departments, and industry, and be operated under the broad guidance of the Interdepartmental Committee.

II. NEED FOR FACILITIES

A. Existing radiation sources used to irradiate food are inadequate in size and characteristics, and are generally located at some distance both from the source of food supply and the laboratory which is supervising research and development efforts. To provide proper process control of the radiation processing experiments, the irradiation sources should be located close to the source of food supply and the research laboratory. Much of the food now being irradiated in the research program is frozen or refrigerated for extended periods prior to irradiation resulting in the introduction of undesirable conditions.

B. Irradiators are needed to develop and demonstrate the best and most economic methods of food radiation processing under a wide variety of product conditions. It is to be emphasized that the development work to be carried out is on both the techniques of radiation processing of foods and the quality of the resulting product.

C. Fixed facilities will meet some of the existing requirements. Certain food studies, however, must be carried out using fresh harvested or fresh processed local varieties of food. Mobile food irradiation units with approximately 100,000 curies of cobalt 60 or the equivalent X-rays from a low-energy electron accelerator will fulfill this need. The value of these units would be enhanced

through their being shared by several users. This is feasible since peak demands and program requirements relative to various food items will vary throughout the year and from one area of the country to another. The cobalt 60 irradiation units could be mounted on special trucks or flatcars providing adequate shielding of the source during transport. These units would be staffed by trained personnel for effective and safe utilization. The mobile irradiators would be administered from a home base which would also provide the operational personnel for the units. Additionally, several small-scale research irradiators with approximately 10,000 curies of cobalt 60 or the equivalent X-rays from a low-energy electron accelerator each will be required to investigate fundamental research problems such as the biochemical effects in radiation processed foods and the origin and control of organoleptic factors (see app. A).

D. These facilities would retain focus on the United States as a leader in the field of food irradiation. They would provide a visible and substantial contribution to technical assistance for less developed countries. This would be done by performing research and development processing in food preservation applicable to these less developed countries and by acting as the training centers for personnel from foreign countries.

III. TYPES OF IRRADIATION FACILITIES

A. Research irradiators

Four research irradiators are proposed for conduct of fundamental studies necessary for developing radiation processed foods. Interest has been expressed for two each of these irradiators for the Department of Agriculture and Department of the Interior.

B. Mobile irradiators

1. *For fruits, vegetables, and grains.*—A mobile irradiator is proposed for use by the Department of Agriculture in the continental United States for studying self-life extension fruits and vegetables and disinfestation of grain.

2. *For tropical fruits.*—A mobile irradiator is proposed for use by the Department of Agriculture in Hawaii to study the disinfestation of tropical fruits.

C. Fixed irradiators

1. *For marine products.*—A marine products processing irradiator is proposed for use by the Department of Interior and should be located near an important east coast fishing port. Note that need for this irradiator would be eliminated if the national center were built in a suitable geographic area since it could be utilized in part for this purpose.

2. *A national center.*—Among the facilities should be one having sufficient flexibility to investigate those radiation process variables that the program thus far has demonstrated to be of importance. Such a national center would—

(*a*) Permit study of microbiological safety, depth dose uniformity, and dose rate effects.

(*b*) Permit study of civilian applications for low dose treatment of meat products.

(*c*) Provide adequate process control to assure reproducibility of end product.

(*d*) Provide a supply of radiation processed foods for testing acceptance, palatability, and storage characteristics.

(*e*) Promote interest and participation of industry in radiation processing of foods.

(*f*) Develop process specifications and quality control factors.

(*g*) Study radiation effects on containers.

(*h*) Give indications of costs, to include capital, operating, and cost per pound for radiation processing of foods.

Cobalt 60 complex.—Cobalt 60 has been selected as the principal radiation source for the national center because of its properties of being neutron-free, readily reproducible, and reliable. The proposed cobalt 60 irradiator is capable of processing in excess of 500 megarad pounds per hour of food. The uniquely flexible source is designed to solve process development problems relating to microbiological safety, depth dose uniformity, product quality control, variable dwell time and evaluation of products using variable source and conveyor configurations. This irradiator requires about one million curies of cobalt 60, a cave with a water pool storage facility, labyrinth entrance, and a simple flexi-

ble conveyor. The estimated total cost of the facility is $1.1 million including cobalt 60 and 10 percent overall cost contingency. It will also be desirable to examine the suitability of low-energy electron accelerators for the radiation processing of foods.

Supporting food preparation, laboratory, and office building.—The building proposed to support food research and process development requirements contains approximately 10,000 square feet. Food preparation will be performed with institutional-type equipment requiring manual operation. A suitable refrigeration area will be provided. The laboratory area will provide for chemical quality control tests, microbiological tests, dosimetry tests, and taste acceptance tests. If the Army builds facilities which are adequate for a national center, the Interdepartmental Committee and the operating agency should seek an arrangement for access to it.

IV. ALTERNATIVE RECOMMENDATIONS DEPENDING UPON ACTION ON DEPARTMENT OF ARMY PROGRAM

In this report it has been assumed that the Army program will continue as proposed by the Quartermaster Corps and that it would require at least partial use of facilities comparable to the national center. Should these assumptions prove incorrect, it is to be noted that—

1. The food throughput of the national center for low dose substerilization treatment would be far in excess of the near term civilian program requirements;
2. The immediate civilian program requirements could be met by research and mobile irradiators; and
3. The Atomic Energy Commission presently has under construction a radiation engineering facility at Brookhaven National Laboratory, which with some modification, could meet the product and process development objectives envisioned for the national center relative to the civilian program, including the limited amount of product irradiations foreseen (see app. B).

If the Army does not build an irradiation facility for its own use, and in addition cannot justify sharing the use of a national center to furnish radiation services for its program, then it is recommended that construction of the center be deferred. In addition to the mobile and research irradiators previously mentioned, it is recommended that a marine products irradiator be established as identified on page 24 of the report. In these circumstances, the operating budget estimates would require reconsideration.

V. COST ESTIMATE FOR IRRADIATION PROCESS RESEARCH FACILITIES

		Plan including national center	Alternate plan
Fixed research irradiators (4)		$200,000	$200,000
Mobile irradiators (2)		400,000	400,000
Fruits, vegetables, grain	$200,000		
Tropical fruits	200,000		
National center [1]		1,400,000	
Marine products irradiator [2]			550,000
Total		2,000,000	1,150,000

[1] Assumes cobalt 60 could be provided at Army price. Not required if Army funds presently held by AEC for a gamma facility are available to build a center to which the civilian program has access.

[2] This irradiator would be needed only if the national center were not built or was constructed in an unsuitable location.

VI. SCHEDULE

It is estimated that approximately 18 to 24 months would be required to design, construct, and test operate the fixed irradiators.

Appendix A

Importance of Basic Research Studies in Food Science (Chemistry and Microbiology) in the Radiation Processed Foods Program

To evaluate the ultimate potential of irradiation in the processing of foods, basic chemical, and microbiological research studies are needed to provide information not now available designed to circumvent off-flavor and odors that develop in foods such as beef. It may also be possible to decrease, through bacteriological studies, the dosage required to achieve specific preservation objectives. Significant advances cannot be made until such data are available for products of such great importance as meats with the use of sterilizing dosages. These research areas need significant attention, not only to assist in achieving the technological objectives described, but also as a part of the Government's role in support of basic science in the overall atoms-for-peace program. Scientists and other leaders in all countries have looked to the United States for leadership in basic science relating to the potential peacetime use of atomic energy and it is essential that the United States continue to provide this leadership. Full evaluation of the potentials of irradiation in food processing cannot be made without the basic research studies in food science in the areas outlined above. Valid information cannot be obtained from these studies unless the research organizations have available adequate research facilities.

Appendix B

High Intensity Radiation Development Laboratory

The HIRDL to be constructed at Brookhaven National Laboratory, will serve for research and development on the use of high intensity radioisotope sources. This facility will be capable of safely handling 1 million curies of cobalt 60 and much greater quantities of cesium 137. Initially the laboratory will be loaded with 500,000 curies of cobalt 60.

The building will contain small research laboratories and two large hot cells with remote handling equipment and a canal. One of these hot cells, the experiment preparation cell, will receive radiation sources directly from either nuclear reactors or fission product separation plants. It will be used to handle, clad, weld, and safey test source containers. The sources are then transferred via the canal to the second hot cell, the experiment irradiation cell.

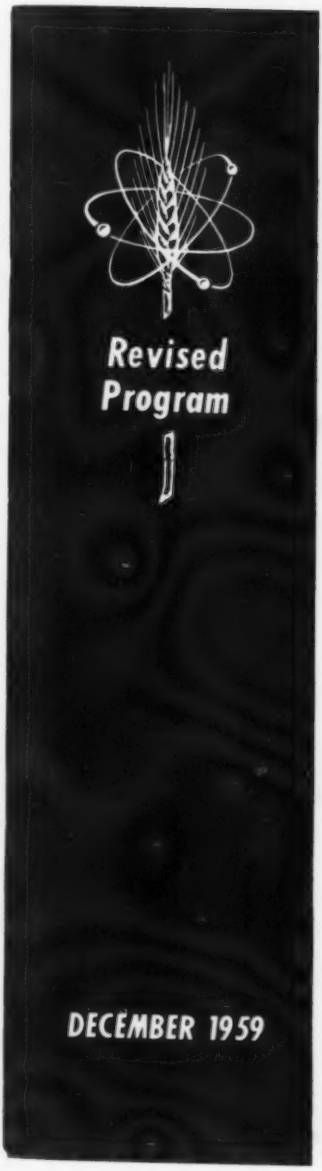
In the experiment irradiation cell, detailed measurements will be made of the radiation fields created using various geometric arrangements of the fabricated radioisotope sources. Experiments will include irradiation of different target materials representative of commercial items such as food, drugs, and chemicals, that might be treated in a large irradiator.

The program with this new facility will include experimental studies of factors affecting the design of large irradiators, such as radiation dose delivered at different points within a target, source dimensions, target dimensions, optimum source and cladding dimensions, optimum design of high efficiency irradiators, heat generation and dissipation in high level sources, and radiation damage to source materials.

Work of this facility will provide sufficient experimental and engineering data to permit private groups to design high level irradiators for particular commercial operations.

Additional facilities necessary at Brookhaven to meet requirements for a food program would be food preparation storage, handling and transportation facilities, and also laboratory space and equipment for evaluation of foods prior to and after irradiation. Throughput capacity would be several hundred pounds per hour at moderate dose treatment (0.5 megarad). The facility could handle packages approximately 16 by 20 by 6 inches.

The HIRDL is expected to have undergone trial runs and be available for product irradiation about July 1962.



FOOD PRESERVATION BY IONIZING ENERGY

DEPARTMENT OF THE ARMY, OFFICE OF THE QUARTERMASTER GENERAL

Revised Army Program

on

FOOD PRESERVATION BY IONIZING ENERGY

14 December 1959

Department of the Army
Office of The Quartermaster General
Washington 25, D. C.

QMGRE 14 December 1959

Lt. General Arthur G. Trudeau
Chief of Research and Development
Department of the Army
Washington 25, D. C.

Dear General Trudeau:

The revised program for the radiation processing of food, requested in DF from your Office dated 2 October 1959, is hereby submitted.

Analysis of actual experience in previous wars and of the concepts of modern combat reveals a great military need for the development of the process of preserving foods by ionizing energy.

Through judicious collaboration with other Government agencies and industry, the Army's activities in this area can also make major contributions to the civilian economy.

The relevance of the program to the Nation's Atoms-for-Peace Program is also clear. There is undisputed world-wide acknowledgment of United States leadership, which should be maintained.

Considerable momentum has been generated. Much progress has been realized and the results are encouraging. This does not mean, of course, that success is assured. There are still risks inherent in pioneering ventures of this magnitude. But these risks are reasonable in the light of the interests of the Army and the Nation.

Early attainment of our objectives can be realized through the vigorous pursuit of the program presented herein. Your approval is requested.

Respectfully,

1 Incl
Plan

A. T. McNAMARA
Major General, USA
The Quartermaster General

PART A

PROPOSED REVISED PROGRAM

I. POLICY

Inasmuch as nonmilitary departments are beginning to be in a position of carrying leadership responsibilities for the national Atoms-for-Peace Program in radiation processing of foods, the Army will affect a smooth transition toward focussing on military requirements. Research will be directed toward the objective of procurement from the civilian economy of the first generation of a relatively few food items of important military significance. The developmental lead time will be compressed to the maximum extent feasible.

Inasmuch as the Army's activity will continue to serve as the backbone of the Nation's effort in this program area, generous collaboration will be extended to other organizations in the joint advancement of the President's Atoms-for-Peace Program.

Inasmuch as an adequate civilian production base is required before military subsistence requirements can be met, cooperation with American industry will be encouraged. Furthermore, information will be disseminated as widely as feasible in order to increase technical know-how in this country.

II. SIX-YEAR OBJECTIVES

1. To obtain wholesomeness clearances permitting unrestricted use of foods preserved by ionizing energy.

2. To advance the technology of food radiation processing so that the following items of military significance and of quality far superior to analogous items available in the combat theatre can be procured:

   a. Sterilized pork, smoked ham, chicken, and beef.

   b. Two or more pasteurized* items.

3. To formulate such items into logistic-saving components for use in all Army ration systems from those in the support areas to and including individual military feeding in the forward areas.

4. To develop components meeting special requirements of the Navy, Air Force, and Marines.

5. To develop process engineering data for efficient transition into industrial sponsorship.

6. To determine, within the coming 3 years, whether the transition pilot-production plant will be built by industry, the Atomic Energy Commission, the Army or another organization, and to effect the necessary transfer of relevant know-how.

7. To conduct timely economic analyses.

8. To establish a reservoir of basic information for future improvement of radiation processed foods.

* Not in the traditional meaning of heat treatment.

III. RESEARCH AND ENGINEERING PHASES

The program will be channelled essentially into the following tasks: Military applications and economic analysis, Assurance of wholesomeness, Development of military rations, Destruction of microorganisms, Nuclear effects on foods, Troop testing, and Development of packaging.

Prime interest will be focussed on four sterilized meats and their combat ration formulations. Secondary attention will be devoted to fresh fruits of high morale value. A description of the seven tasks is given below. The starting point in each of these tasks is the present state of the art, which is summarized in the Appendices. At the same time, they have been pointed directly toward the immediate six-year military objectives, delineated in Section II.

1. Military applications and economic analysis.

Attention will be devoted toward completing a comprehensive operations analysis to determine the logistic, operational and economic aspects of incorporating radiation processed foods into the combat feeding system of the armed forces. The studies will consider both limited and general warfare. Comparisons will be made between foods preserved by radiation and by other processes, together with the respective roles to be played by each in the optimum overall combat feeding system.

2. Assurance of wholesomeness.

This phase will continue to be directed by The Surgeon General and logistically supported by the Quartermaster Corps. The protocol under which the work is to be continued has been developed with full cooperation and concurrence of the Food and Drug Administration. It has been designed to result in clearances for unrestricted consumption of radiation processed foods by both military and civilian populations. Included are six principal sub-phases, namely:

a. Short term feeding to animals, principally rats, which has been completed.

b. Long term feeding of 21 representative foods to each of 2 species of animals for 2 years, followed by comprehensive histopathological examinations. The feeding work is 90 per cent completed. The tissue evaluations, which will be done by the Armed Forces Institute of Patholo[gy] are currently in progress.

c. Carcinogenicity and enzyme studies which are approximately 50 per cent completed.

d. The resolution of several experimental anomalies, which have been noted in long-term animal feeding. These will require effort beyond that already in progress. Additional work in two areas, possible sterility in dogs and possible auricular rupture in mice, may extend over a period of 3 years.

e. Additional new work with regard to the biological aspects of possibly induced radioactivity.

f. Human feeding studies. Those conducted for evaluation of acceptability of radiation processed foods have been deferred pending the determination of residual induced radioactivity. It appears that the tests may be resumed in the not too distant future. Long-term human feeding will await adequate resolution of the animal anomalies and conclusive information on induced radioactivity.

3. Development of military rations.

Early efforts will be directed toward meeting requirements of field Army feeding. Usable sterilized beef, pork, chicken, and ham items in the individual combat meal and small group operational rations will be developed in accordance with CDOG. In addition, the use of these prime components, either sterilized or pasteurized, as logistic-saving components in A and bulk B rations will be pursued. Morale-significant items, such as fresh fruits, will constitute a tertiary goal.

Processed foods will be studied with regard to their retention of color, flavor, texture, and nutritional quality. Pre-irradiation and post-irradiation factors will be considered, in addition to those acting during the exposure period. Interactions among these factors will also be taken into account.

Pre-irradiation processing treatments which will be investigated will include precooking techniques such as steaming, roasting, broiling, and frying; time, temperature and method of heat application for enzyme inactivation; addition of salts, tenderizers, flavor accentuators, spices, and off-flavor suppressants; headspace composition; and oxygen odor scavengers.

The effects of processing conditions accompanying irradiation will be explored. Among those which may have significant influence on product quality are dose rate, dose fractionation, product temperature, and gaseous exchange.

Among the post-irradiation factors which will be studied are: the influence of residual enzyme activity, cause of excessive softening, time-temperature condition conducive to product improvement, interactions between various components of formulated products, interaction between food and package, and time-temperature effect on general chemical degradation of stored irradiated foods.

A fundamental research program will be continued concurrently to determine the origin of the organoleptic changes, the mechanisms whereby they occur, and means for their control. Initially, this sub-phase will be focussed principally on beef.

Studies will be conducted on identification of chemical changes occurring during the irradiation of meats, and subsequent storage under a variety of time and temperature, dose, dose rate, headspace composition, and additives.* Fractionated meat components and model systems of proteins and lipids will be studied to provide an understanding of the underlying reactions.

Optimum characteristics of odor scavengers, which are effective in "dry" packs, will be established. Further research will be undertaken to develop scavenger systems which can be effectively utilized with "wet" packs.

The mechanism of proteolytic enzyme reaction will be studied, with the hope of improving methods of enzyme control, superior to the present blanching technique.

4. Destruction of microorganisms.

Basic research will be conducted on the physiology and biochemistry of microorganisms with special emphasis on anaerobic spore formers of public health significance. The mechanism of action of ionizing energy on the various stages of development of these microorganisms will be determined.

A clear understanding of the influence of a variety of processing and substrate factors will be sought in order to develop conditions whereby foods can be safely irradiated at substantially lower doses than presently adopted to gain quality and economic advantages. Some of the processing factors will include: dose, dose rate, dwell time, beam spectra, heat-interaction, energy pulsing, and temperature. Some of the substrate factors to be analyzed are: type of food, moisture, pH, strength of inoculum, and chemicals.

* Usual sense of the term, not legal sense.

Studies to determine the particular types and strains of Clostridium botulinum which are the most radioresistent will be undertaken in order to establish a definitive sterility reference for processing by ionizing energy.

5. Nuclear effects on foods.

The pertinent isotopic content of selected foods of interest will be determined by literature analysis and experimentation. Efforts will be expanded to determine the probability and theoretical and measurable amounts of activity induced in actual food items and in food "phantoms" by radioisotope, spent fuel rod, and electron beams of various energies.

A quality control procedure will be developed, which will be used to guarantee radiological safety of treated foods as established by Food and Drug Administration, Public Health, Atomic Energy Commission, and the Army Surgeon General, leading to early resumption of human feeding studies and eventual general acceptance of food so processed.

The above studies will be coordinated with The Surgeon General, particularly with reference to biological interpretations of the resulting data.

6. Troop testing.

Troop-feeding tests will be conducted on two levels following approval by and with the collaboration of The Surgeon General. The first, designed to determine acceptability, consists of single meals to about 200 soldiers per test. The second, designed to measure monotony factors and field utilization, will be operated as engineering tests.

An engineering test will be based upon 100,000 meals containing about 5.5 oz of irradiated meat per meal. About 2 to 4 engineering tests per year will be conducted, once the approved irradiated items can be provided.

7. Development of packaging.

Only minor studies will be conducted on tin plate cans, which have been shown to meet minimum requirements as a container for irradiated foods. Extended storage involving aluminum cans will be completed.

Investigations on flexible and semi-rigid containers will be directed towards material development and container design. An evaluation will be made of the nature and amount

52249 O—60—pt. 1——11

of extractives and possible induced radioactivity produced in various plastics by the irradiation process. Means of controlling the production of these substances will be sought. Work will be directed toward the development of new laminates with improved resistance to ionizing energy, in addition to the normal attributes of useful containers.

Container design will be undertaken toward saving weight and cube, as well as withstanding rough handling and long-term storage.

IV. COORDINATION WITH OTHER ORGANIZATIONS

Full advantage will be taken of the capabilities and knowledge of all American organizations by the Medical Corps and the Quartermaster Corps.

Within the Army, CONARC, CDEC, and other elements will be consulted in the conduct of operational analyses of irradiated foods in the Army subsistence complex.

Collaboration will be maintained with the Navy, Air Force, and Marine Corps in meeting their special requirements.

Overall coordination with other government agencies will be affected through the Interdepartmental Committee on Radiation Preservation of Foods. Intimate bilateral working relations will be maintained especially with the Atomic Energy Commission, the Department of Health, Education and Welfare, the Department of Agriculture, the Department of Interior, and the National Bureau of Standards on special work phases of mutual interest.

Liberal advice will be sought from various quasi-governmental bodies, such as the National Research Council.

The major portion of the actual research itself will be conducted by private industry and universities, although irradiation services from central sources will be provided. The plans and results of all workers in the program will be closely coordinated.

V. FACILITIES

Maximum use will be made of facilities available in industrial and academic institutions, in addition to those currently present in government establishments. The state of progress in the program is advancing at such a pace and in such a direction, however, that a moderate research facility is now needed to carry out necessary investigations. Such a capability had been originally incorporated in the deferred USAIRC. Because of the disapproval of the Center, the research portion must now be made available separately. Several of the more significant considerations are outlined below.

Because of the presence of neutrons in the gamma flux surrounding fresh fuel elements in water, it would not be advisable to rely on them as a source of radiation for foods for long-term human testing. Older fuel elements are relatively free from neutron producing gamma photons. But in this case, the gamma flux is too low for the purposes planned. The obvious desirable source from the standpoint of radiological safety is cobalt-60. The availability of such a source as soon as practicable is essential for major advance in the program, particularly in the human feeding phases. At the present time, adequate sources of cobalt-60 are not available. Based on an Army research requirement 2 years hence of about 50 tons of gamma-treated food per year; of a reasonable source time for research on such problems as source geometry, dose distribution in containers of different sizes and shapes, and flux uniformity of radiation field for use by other Government agencies; and for irradiation services to industrial collaborators, it is estimated that about a megacurie of cobalt-60 will be required.

In order to provide the minimum amount of laboratory support, a small food sampling, preparation, and testing annex will be needed as an adjunct to the gamma facility.

The requirement for a source of electrons at the same location has been carefully considered, in view of the availability of a partially completed linear accelerator. There are good grounds to believe that future costs of commercial processing may favor electrons significantly over radioisotopes for some commodities. Certain treatments, such as restricted surface irradiations, can only be carried out with electrons of specified energies. It would be desirable on this basis, that electrons continue to be investigated.

Furthermore, there is much debate over the possibility

of induced radioactivity by electrons beyond certain energy thresholds. The present wholesomeness and toxicity program is based on fuel rods and cobalt-60 as a source. However, the Food and Drug Administration has indicated these data may be extrapolated to an electron source with energies up to 5 mev. If energies above 5 mev are to be used, then a new wholesomeness and toxicity program must be undertaken. It is the opinion of The Surgeon General that, based on present data, the use of an electron accelerator with energies above 5 mev will produce amounts of induced radioactivity in food to make it unacceptable on the basis of wholesomeness and toxicity. The precise value at which induced radioactivity occurs experimentally is unclear. To determine this a variable, carefully controlled, well calibrated accelerator is required with sufficient energy peak exceeding either the level of intended use in food processing or that of measurably induced radioactivity. To clarify the question of radiological safety of electron-irradiated foods, an accelerator of reasonable energy peak will be necessary. Since there are indications that the Food and Drug Administration will, with time, rely on actually measured quantities instead of theoretical values, it would be desirable to accumulate the needed data in the meantime.

It is highly probable that at least spot checks will have to be carried out with electron-treated foods above 5 mev in a representative number of animal feeding tests before wholesomeness clearance for foods processed in this manner is given by responsible authorities. For this purpose it is important that the characteristics of the electron source be readily controllable and well calibrated. This would be particularly true when comparative tests involving electrons at different energies are to be conducted. It would also be desirable that the electron source be situated at the same location as the gamma source. This will enable careful comparisons of the two sources with regard to effects on foods, efficiency of energy absorption, dose distribution within the samples, and other factors. Careful experiments of this kind have not been done. They should precede the finalization of Army specifications for the procurement of irradiated foods. Considering the valuable and needed data which can be obtained, the Army should complete the present linear accelerator. In order to realize this at a reasonable cost, the design criterion should be reduced from peak energies of 24 mev to 12 mev.

The actual cost of the needed research facility cannot be determined without negotiations with potential contractors. Estimates are as follows: Cobalt-60 Irradiator, $1,100,000; completion of linear accelerator, $400,000; Food laboratory annex, $300,000. Total estimated cost amounts to $1,800,000.

It is to be noted that the Atomic Energy Commission endorses the plan for additional irradiation facilities to support the program, particularly cobalt-60. However, the Commission does not concur in the need for the linear accelerator. (See AEC letter in Section XIV).

Discussions with representatives of the Commission and reconsideration of the need for the linear accelerator in the light of their reasons led the QMC to conclude that the Army's interest still requires that the linear accelerator be completed.

The specific location of the research facility will be determined after a careful survey of the various possibilities in the light of the approved Army revised program.

No plan is being forwarded at this time concerning a pilot-production plant. Intensive efforts will again be made to see whether industry or another government agency would be willing and able to construct this necessary transition plant at the appropriate time.

VI. FUNDING

The required funding is shown in Table I. It is to be noted that the Atomic Energy Commission has an unexpended balance of approximately $2,100,000 as of this date. This money can be applied toward certain phases of the project funding, if approval is granted.

Breakdown of the figures follow the work phases described in Section III. The last entry covers the cost of radiation services furnished the various research contractors. The principal concerns providing the service to date have been Material Testing Reactor, Dugway Proving Ground, High Voltage Engineering Corporation and General Electric. With the completion of the proposed research facility, most of these particular services will no longer be required. The funds budgeted for the subsequent years will be used for the operation of the facility.

The cost of food for troop testing is not included in this budget.

Table I

RESEARCH AND DEVELOPMENT BUDGET

FISCAL YEAR	61	62	63	64	65	66
Military applications and economic analysis	80,000	80,000	--	--	50,000	--
Assurance of wholesomeness	300,000	250,000	200,000	100,000	50,000	50,000
Development of military ration	440,000	380,000	320,000	300,000	150,000	125,000
Destruction of microorganism	90,000	80,000	60,000	50,000	25,000	25,000
Nuclear effects on foods	50,000	50,000	40,000	40,000	--	--
Troop testing	35,000	60,000	60,000	50,000	40,000	30,000
Development of packaging	90,000	100,000	100,000	50,000	25,000	25,000
Radiation services	180,000	180,000	180,000	180,000	180,000	180,000
TOTAL	1,265,000	1,180,000	960,000	770,000	520,000	435,000

FACILITY BUDGET FY '61*

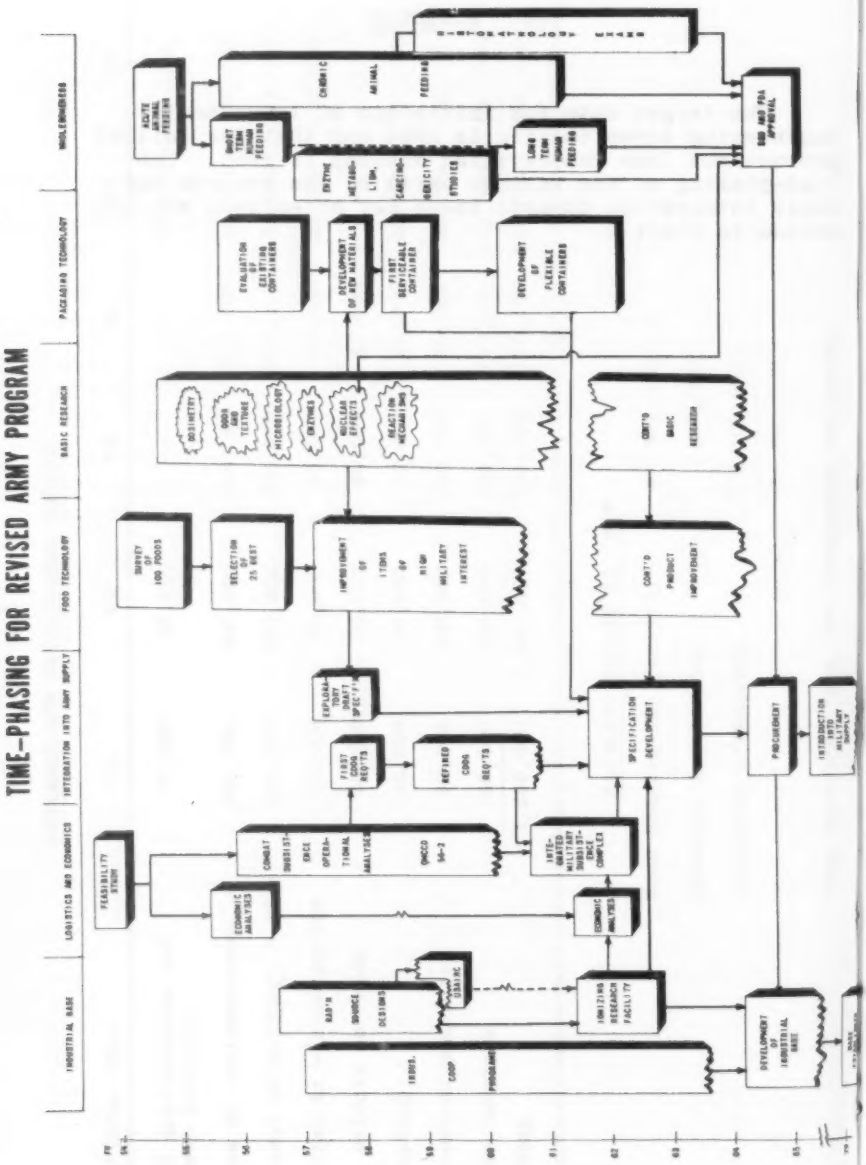
Food Preparation Facility	$ 300,000
Electron Accelerator	400,000
Cobalt-60 Irradiator	1,100,000
Total	$1,800,000

*Can be funded from AEC unexpended R&D funds

VII. SCHEDULE

The target date for initiation of large scale engineering troop testing is 1964 and that for initial procurement from the civilian economy is 1966. The time-phasing of the various parts of the program and their integration towards these key objectives are presented in Chart 1.

*Can be funded from AEC unexpended R&D funds


TIME-PHASING FOR REVISED ARMY PROGRAM
INDUSTRIAL BASE
LOGISTICS AND ECONOMICS
INTEGRATION INTO ARMY SUPPLY
FOOD TECHNOLOGY
BASIC RESEARCH
PACKAGING TECHNOLOGY
WHOLESOMENESS
SURVEY OF 100 FOODS
SELECTION OF 25 BEST
IMPROVEMENT OF 5 ITEMS OF HIGH MILITARY INTEREST
DOSIMETRY
BODY AND TEXTURE
MICROBIOLOGY
ENZYMES
NUCLEAR EFFECTS
REACTION MECHANISMS
CONTD BASIC RESEARCH
EVALUATION OF EXISTING CONTAINERS
DEVELOPMENT OF NEW MATERIALS
FIRST SERVICEABLE CONTAINER
DEVELOPMENT OF FLEXIBLE CONTAINERS
ACUTE ANIMAL FEEDING
SHORT TERM HUMAN FEEDING
CHRONIC ANIMAL FEEDING
ENZYME
METABOLISM
CARCINOGENICITY
TOXICITY
LONG TERM HUMAN FEEDING
SUB AND FDA APPROVAL
CONTD PRODUCT IMPROVEMENT
EXPLORATORY DRAFT SPECIFICATION
FIRST DRAFT SPECIFICATION
REFINED CORE REQ'TS
SPECIFICATION DEVELOPMENT
PROCUREMENT
INTRODUCTION INTO MILITARY SUPPLY
FEASIBILITY STUDY
ECONOMIC ANALYSES
COMBAT SUBSYSTEM EFFECTIVENESS OPERATIONAL ANALYSES
SNACC 54-2
INTEGRATED MILITARY SUBSYSTEMS COMPLEX
ECONOMIC ANALYSES
R&D'N SOURCE DECISIONS
IRRAD. CORP PROGRAMS
IONIZING RESEARCH FACILITY
DEVELOPMENT INDUSTRIAL BASE
FY 54
55
56
57
58
59
60
61
62
63
64
65
70

PART B

APPENDICES

VIII. DESCRIPTION OF PROCESS

Unique changes are brought about in foods exposed to ionising radiations. When employed in relatively low amounts, the treatment inhibits the sprouting of certain tubers. With slightly higher amounts, insect life and disease-causing worms are killed. With much higher amounts, most microorganisms are killed and the chill shelf-life of many fresh foods can be extended significantly. At the highest levels encountered, all microbial life is destroyed and the food is freed from microbiological spoilage even when subsequently kept at room temperatures.

In practice, the prewrapped food package is subjected to the rays for a matter of seconds or minutes, depending upon the strength of the radiation sources. During the process, the temperature of the food is not increased beyond a few degrees. It is not the temperature therefore that brings about the biological effects. It is the ionising action of the penetrating energy that is responsible.

Up to now, man has learned to use drying, pickling, salting, smoking, freezing, and heating in preserving foods. These latter methods exert their influence primarily through the molecular aspects of the system. With gamma rays, however, we are dealing with energies originating within the atom and/or nucleus. The rays are emitted as a result of intra-atomic adjustments. In travelling through the food, they produce both molecular and atomic changes.

Most conveniently, the radiation takes the form of a beam of electrons or a flux of gamma rays. The electrons are usually generated from machines, while the gamma rays are emitted by radioisotopes made in atomic reactors. For proper results the radiations used should be sufficiently energetic to attain the desired penetration of the food package, yet at the same time not such as to induce harmful radioactivity nor other unacceptable changes in the food itself.

IX. MILITARY REQUIREMENTS

1. Historical perspective.

The basic importance of an adequate and wholesome supply of food to fighting forces has been acknowledged from the very beginning of organized warfare.

The most important components of the American military ration have always been the two common staples of bread and meat. The latter is by far in greatest demand. Approaching bread and meat in importance are fresh vegetables and dairy products.

History has shown that an Army subsisting on nothing but processed foods soon undergoes degradation in health, morale, and fighting effectiveness unless reasonably fresh foods are made available on occasion. Armies are forced to subsist on dried, canned, dehydrated, and other processed foods when fresh meat and produce were not available. Under these circumstances, however, men soon foraged the countryside for fresh food whenever the opportunity presented itself and at times even at the risk of life. To conclude, therefore, that the combat soldier in a future conflict will be prone to none of the foregoing when required to subsist entirely on canned or dehydrated foods, because of a command decree that the nature of the conflict will not permit the luxury of supply of fresh staples to the fighting forces, is contrary to historical facts. Past changes have not altered the soldier's desire for fresh foods, nor is it conceivable that modern changes in warfare will do so.

The conventional method of supplying fresh meat and produce, as applied in World War II, required a global refrigeration transport and storage capability far beyond that which could be established and/or maintained. The disparity between the demand for fresh food and the logistics to supply this food becomes far more aggravated when current concepts of dispersion and mobility, coupled with the destructive capability of an enemy, are involved. Accordingly, the Army probed into radiation preservation of food as a potential toward meeting this problem, because of the accepted fact that fresh meats and produce will continue to be important components of the military subsistence complex in any future conflict no matter what form the doctrine or tactics may take.

2. Civilian habits influencing the acceptable quality of combat rations.

The American military force in peace and war is

primarily one of citizen soldiers. The citizen soldier enters the military service accustomed to food and food habits acquired and enjoyed in civilian life. The degree of acceptance or rejection of military subsistence, therefore, is a function of its disparity in kind, quality, and taste to what has been customary. Accordingly, the military food program has been based on the premise that all troops will be fed the most nutritious food available, approaching accustomed taste, and in the most appetizing form within the realm of reasonable practicability. This policy has applied particularly to troops in combat. The Quartermaster Corps does not foresee a reversal of this policy.

Americans entering the military services in World War II brought with them food habits and tastes based on the standard of living enjoyed immediately preceeding 1941, and accordingly rated the then available military subsistence in relation to this standard.

The Army was prepared for that war with two established special-purpose rations, field ration D and field ration C, in addition to the bulk B and A rations. The use of the special-purpose field rations not only revealed their inability to satisfy the many feeding problems imposed by the new combat conditions but also led to abnormally low acceptance of the rations because the lack of variety forced repetitious feeding of the same type of item. This necessitated the development and introduction of a succession of combat field rations which had to be developed in haste by trial and error, which incurred waste that could have been avoided by an earlier and orderly development program.

A review of civilian consumption data of a few major food products will serve to illustrate changes in American eating habits, which the Army must take into consideration in its subsistence development program. The per capita consumption of meat has increased from a 1935-39 average of 127.0 pounds to an average of 148.5 pounds in 1947-49, and to an average of 156.5 pounds in 1957-59. A projection of the increase to 1975 indicates that the per capita consumption of meat in the United States will reach 180 pounds per annum. The average per capita consumption of chicken has risen from 13.4 pounds (1935-39) to 27.9 pounds (1957-59), while turkey has advanced from 2.2 pounds to 5.9 pounds. Accordingly, it may be concluded that the military subsistence complex of the future must include a higher percentage of meat and poultry than was the case in World War II and even Korea if the Army ration is to keep relative pace with the customs and eating habits

of the population entering into the Armed Forces at some future date.

Furthermore, increase in per capita meat and poultry consumption has taken place in the fresh food area. Therefore, if the Army is to follow this trend there must be a drastic improvement in the canned meat flavor and quality, or a means must be found whereby fresh-like products can be made available without incurring the current logistic impediments that now preclude accomplishment of this objective. The irradiated food process holds promise toward accomplishing this objective.

3. Subsistence for the Army in the field.

The objective of the Army's Simplified Food Logistics Program is to satisfy the requirements of an optimum feeding system for the Army and Army-supported personnel in the theater of operations.

To satisfy the subsistence of an Army in the field, several meal types are required, as shown in Chart 2. These are: Individual meals, Vehicular (squad or crew) meal, Unitized "B" meal, Bulk "B" meal, and Bulk "A" meal. These meals should ultimately:

a. Insure that combat personnel in the forward area will be fed over a sustained period with an adequate and tasteful ration.

b. Eliminate or greatly reduce refrigeration requirements while providing acceptable food products, comparable to their fresh counterparts.

c. Reduce requirements for transport, storage areas, handling equipment, and Class I personnel within the theater of operation.

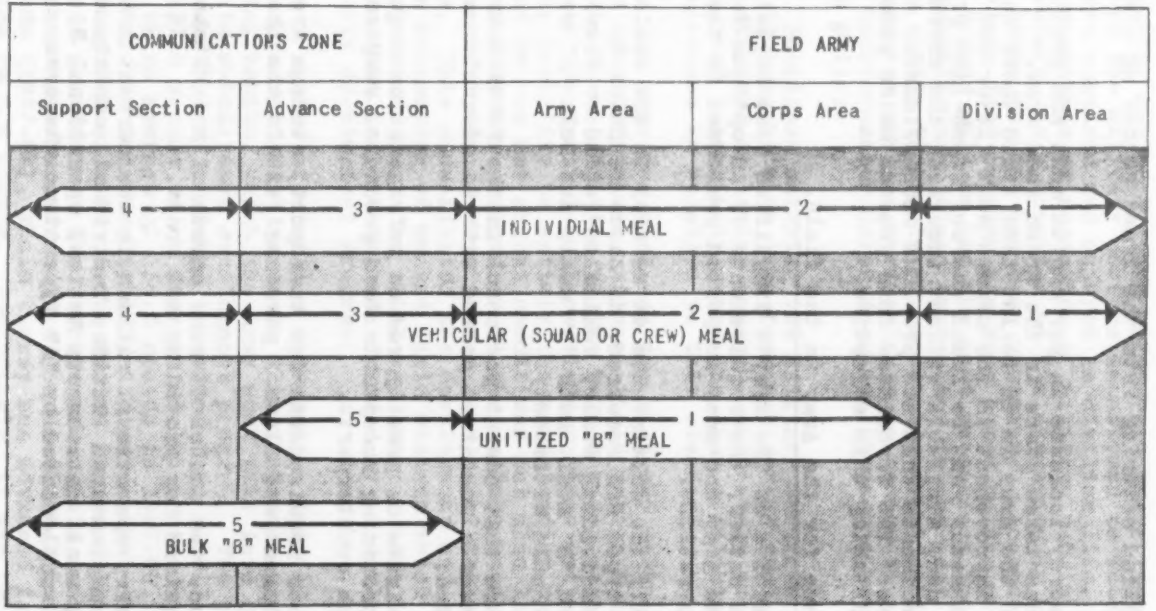
d. Reduce the number of mess personnel and kitchen equipment required for providing hot meals.

The primary operational rations in the current Army subsistence complex are: Ration, individual, combat, meal type; Ration, small detachment; Ration, operational B, which may be supplemented by "A" type items whenever possible.

Logistically, the current operational rations fall short in one or more of the following attributes:

a. Storage life short without refrigeration,

TYPES OF SUBSISTENCE FOR MODERN ERA



LEGEND

1 *Primary Usage*
2 *Substantial Secondary Usage*
3 *Some Secondary Usage*
4 *Negligible Secondary Usage*
5 *May be used depending upon Location on Land Mass & Tactical Situation*

Chart 2

b. Storage space excessive per unit of food,

c. Weight excessive per unit of food,

d. Preparation time excessive,

e. Preparation equipment excessive, and

f. Trained personnel required for preparation.

Operationally, they fall short in that acceptability is only nominal and the monotony factor is high.

4. Army combat feeding situations.

Three types of feeding situations are expected to exist under the concepts of future warfare. These are: Company or larger group size, Small detachment, and Individual.

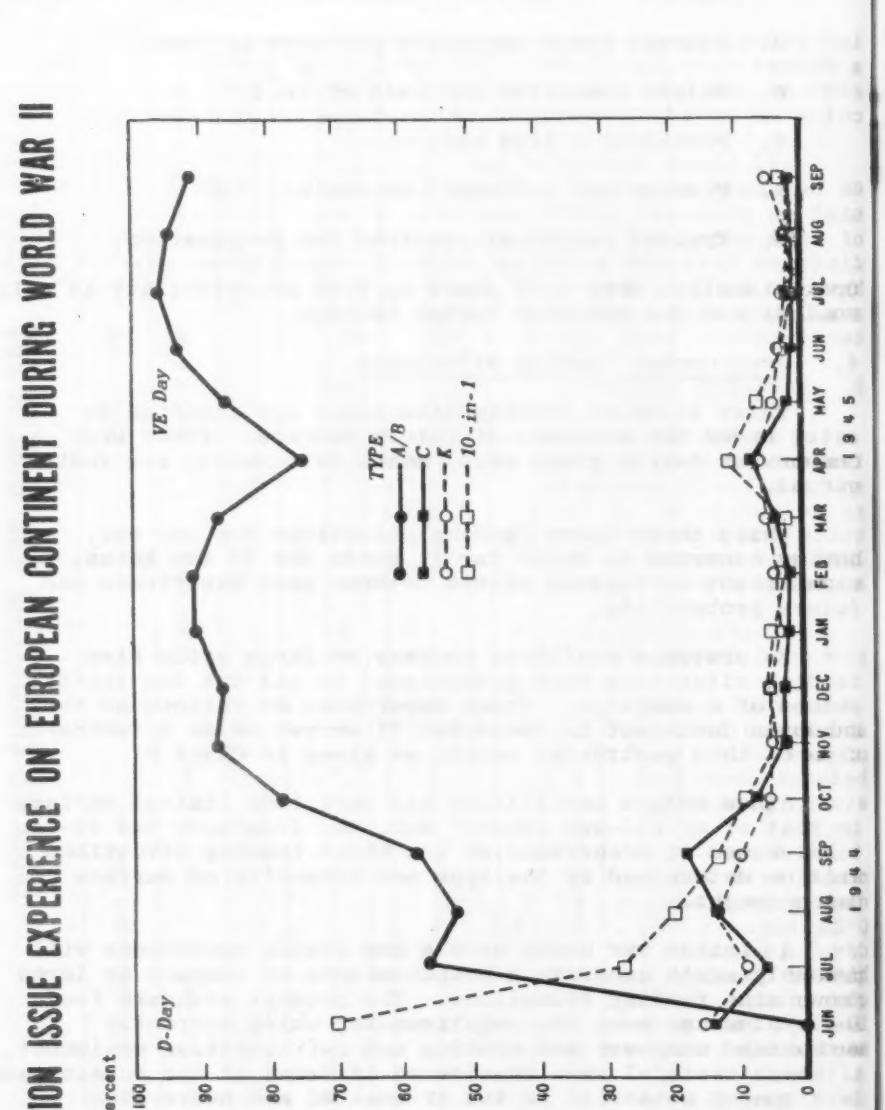
While these three feeding situations are not new, having occurred in World War I, World War II and Korea, a significant difference exists between past experience and future probability.

In previous conflicts company or large group size feeding situations were predominant in all but the initial phases of a campaign. Issue experience of rations on the European Continent in World War II serves as an illustration of this particular point, as given in Chart 3.

Since future hostilities may vary from limited warfare to that of an all-out general war, the frequency and extensiveness of occurrence of the three feeding situations will be determined by the type and intensity of warfare being fought.

A limited war under stable and static conditions will probably again generate a preponderance of company or large group size feeding situations. The present standard feeding system can meet the requirements, using currently authorized manpower and cooking and refrigeration equipment, although wasteful when considered in terms of the subsistence development potential in the irradiated and dehydrated food fields.

The highly mobile, fluid and dispersed operations envisioned in concepts of future all-out warfare impose a requirement for a feeding system having a substantial capability for supporting troops in small detachments and


RATION ISSUE EXPERIENCE ON EUROPEAN CONTINENT DURING WORLD WAR II
Percent
100
90
80
70
60
50
40
30
20
10
0
D-Day
VE Day
TYPE
A/B
C
K
10-in-1
JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
1944
1945

individual feeding situations. It has been estimated that a modern type field Army will require approximately 18 per cent of its meals as individual meals, 48 per cent as vehicular or squad type and 34 per cent as large group type.

If these estimates are accepted as valid, approximately 66 per cent of a modern field Army will be required to subsist on packaged operational ration for substantial periods of time requiring little or no preparation. Past experience dictates that the standard packaged operational rations will have to include a greater variety of items than currently available with considerable improvement in taste and acceptance before they will meet sustained combat requirements.

5. Packaged rations.

As stated earlier the Army entered World War II with two established special-purpose rations, the Field Ration D and the Field Ration C. The Field Ration D was to be used as an emergency ration and as a supplement to other rations. While the D Ration was procured in substantial quantities in 1941 and specifically in 1942, it soon became unpopular as a combat food, requiring discontinuance of this ration.

Chart 4 illustrates the kinds and quantity of ration procured during World War II and subsequent thereto.

Field Ration C entered World War II containing meat and bread components. It had the pre-war characteristics of the 1918 "Reserve Ration" but had a better nutritional balance than its predecessor, fair keeping qualities, and sturdy packaging.

A major problem of the C Ration concerned its meat components and lack of variety. The early waves of criticism were aimed at the monotonous meat diet of the first C Ration. A series of improved C Rations were successfully developed to correct this situation. Each was aimed at a higher quality and taste as well as greater variety of the components of the ration. In addition, a 5-in-1 and a 10-in-1 ration was required to be developed in order to meet combat feeding situations.

Had the field rations not been supplemented almost at the very beginning of World War II with perishable subsistence, far greater criticism and detriment to morale would have insued. The occasional appearance of fresh fruits, for example, had an effect on breaking the downward trend of monotony and loss of appetite in combat troops subsisting on combat rations far greater than the actual amount of fruits served would lead one to suspect.

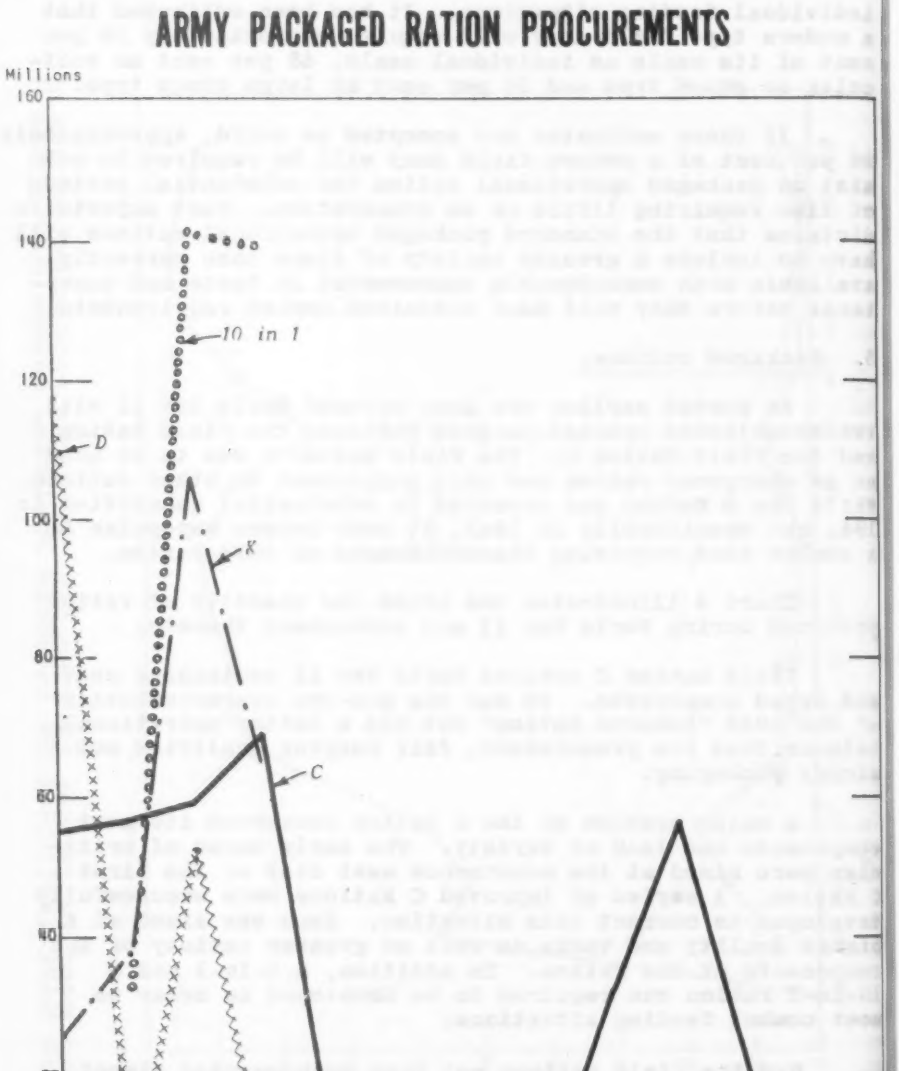

ARMY PACKAGED RATION PROCUREMENTS
Millions
160
140
120
100
80
60
40
20
0
10 in 1
D
K
C
5 in 1
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953

Chart 4

6. Perishable subsistence.

It has been the Army's policy to feed combat soldiers perishable subsistence as soon as combat conditions warrant. Specifically, a definite effort has always been made to supply fresh foods to combat personnel in hospitals and rest areas. Chart 5 gives some indication of the vast quantity of perishable subsistence procured during World War II. During World War II the plan called for a supply of perishables to approximately 40 per cent of the troops ashore by July 1943 and to 90 per cent by the end of the year. The objective of the program was to provide 0.75 lb of perishables per man on continent by January 1945. While this objective may appear modest, problems arising from the lack of available reefer vessels, reefer railroad cars, mobile refrigeration vans, and refrigeration storage facilities seriously affected the attainment of the original objective. In fact, the meat and perishable storage requirements for the continent were deficient to the extent of 6,000 long tons at the end of September 1944 and increased to a deficit of 26,000 long tons by the end of February 1945. This deficit occurred even in the face of an aggressive construction program by the Corps of Engineers building refrigerated storage facilities.

Had the Army had a capability of supplying fresh-like subsistence requiring no refrigeration, an inestimable amount of manpower, equipment, and money would have been saved during World War II.

7. Navy, Air Force, and Marine Corps interests.

The above discussions on military requirements have centered upon Army needs. A similar drastic improvement in combat subsistence is required for the other services. For the Navy the change is typified by the needs of the long-range atomic powered submarines that remain submerged continuously for long periods of time. This was demonstrated in the Fall of 1958 by the 60-day continuous submergence of the U. S. S. Seawolf. The Air Force is faced with feeding problems of flight crews at high altitudes.

"The limiting factors in our submarine endurance have been transferred from the fuel to the food and manpower morale. Actually, one is not more important than the other as they are practically one and the same." This observation was taken from the minutes of the Third Submarine Feeding Seminar, held at the U. S. Naval Supply Research and Development Facility in Bayonne, last June. It shows Navy awareness of a discomforting fact. The expensive, modern, atomic submarine, a powerful weapon in being, can only be fully exploited insofar as the inadequate types of rations available today permit.

PROCUREMENT OF PERISHABLE SUBSISTENCE BY QUARTERMASTER MARKET CENTERS IN WORLD WAR II

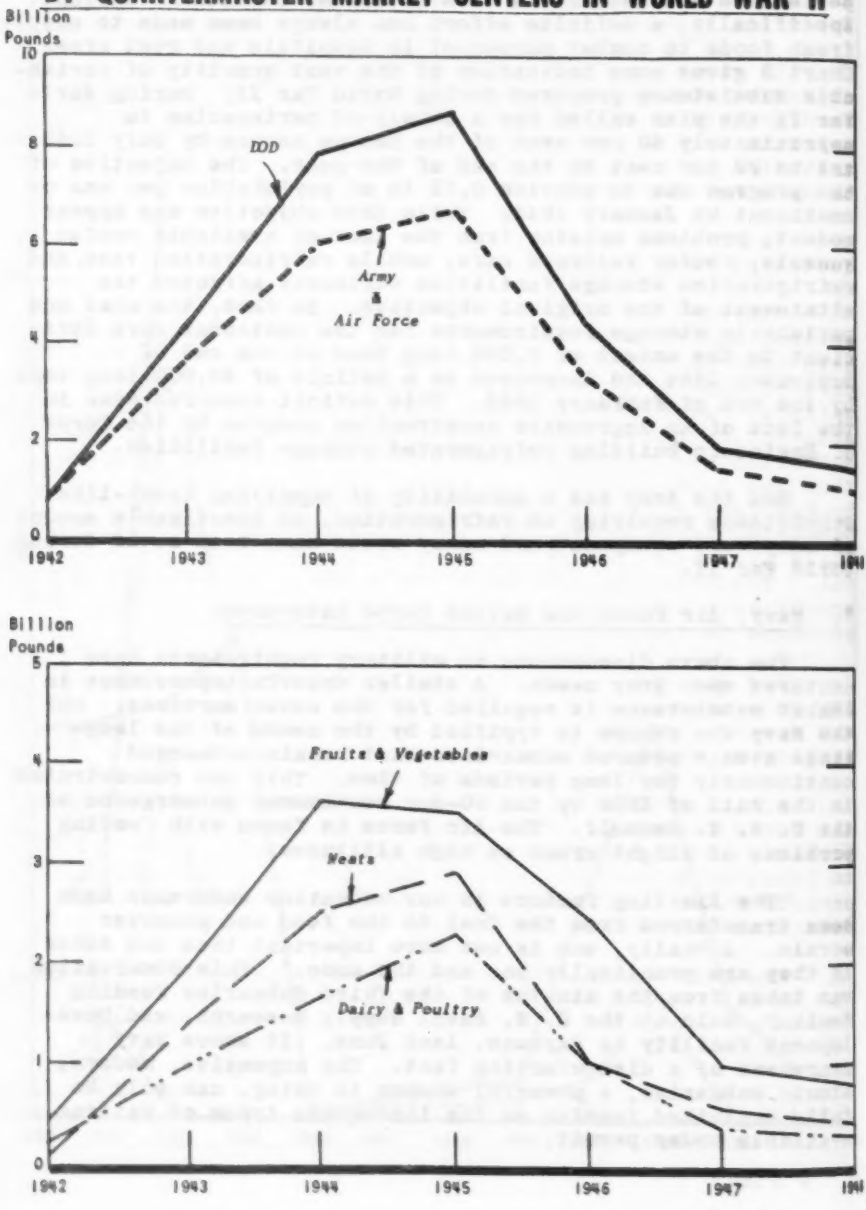


Chart 5

This seminar, which was attended by representatives from BUSHIPS, BUSANDA, BUORD, CINCLANT, SUBLANT, SUBPAC, NSO, various Navy and commercial shipyards, and British and Canadian Navies, was held to review progress in improving submarine feeding since the April 1957 seminar.

It was stated at the seminar that when the Navy speaks of ration endurance, it must consider not only how much food must be placed aboard but also how long the food can maintain morale at a workable level. A significant contribution to the solution of this important problem can be made by radiation processed foods.

The Navy problem is vividly illustrated by another quotation from the same meeting.

"Through the media of personal experience, novels, movies, and TV shows, World War II submarine operations have been revealed as rugged and nerve-racking. While part of this is caused by the very nature of submarine warfare, commissary equipment with poor functional characteristics and utilization of foodstuff ill-suited for submarine use caused some of the difficulties. Recognizing that the submarines of the future could not be fettered by the feeding operations, BUSHIPS, BUSANDA, and the Submarine Force decided to do something about the situation. While progress has been made, it has been slow and painful. Tradition, prejudice, lack of communications, and apathy have militated against a full-scale war on the problems facing submarine feeding of the future."

The Air Force has also made great strides in improving endurance potentials and aircraft maneuverability and speed. Programs of today are projected to the penetration of outer space in the near future.

Again, similar to the Navy's submarine problem, the Air Force faces the problem of maintaining morale at a workable level for its aircrews of the future, forced to function in a confined and limited space for extended periods under conditions that can be considered no less demanding than those imposed by the submarine.

The Marines have made considerable tactical advances

in amphibious warfare. Considerable reliance will be placed on air movement from ship to shore through helicopters or similar carriers. An increased speed of movement from ship to shore and the greater dispersion and longer ranges of operation will be realized. This means that the ground combat situations confronting the Marines are every bit as difficult and trying as the conditions faced by other Services. Again, it would appear that the solution to the problem is not merely a matter of more storage space or altering the food so that it requires less space. A high quality food that can be air supplied to Marines during amphibious operations would certainly do much to improve the morale of the individual man. Here again, irradiated foods will offer a significant contribution to successful combat.

X. CIVILIAN POTENTIALITIES

The fact that innovations for military purposes have repeatedly redounded to the benefit of the civilian economy have been confirmed many times in world history.

The classical case is that of canning, which was stimulated by Napoleon's need for an adequate means of supplying his troops with food. In 1809 Nicolas Appert succeeded in preserving certain foods in especially made glass bottles which had been kept in boiling water for varying lengths of time. Last year, the sales of canned foods in this country amounted to 4.8 billion dollars.

The United States Army itself laid much of the scientific basis for the dehydrated foods on today's market. The fundamental research on the browning, for example, led to greater understanding of the development of good color in dehydrated potatoes and eggs. Much of the more advanced methods of mass-producing dehydrated foods resulted from the large technological effort of Army subsidized programs in World War II. Instant beverages had undergone their trials of initial consumer reactions during the difficult days of the same period. In 1958 over 300,000 tons of potatoes were converted into dehydrated products for civilian sale.

Convenience foods have long been a prime objective of combat rations. The fighting man must conserve time and energy. Deboned 4-way beef is a simple example of the trend in this direction during World War II. We now find the same idea extrapolated to the ultimate in TV dinners.

It is expected that the Army's efforts in developing the preservation of foods by ionizing energy will meet with the same rewarding experience in the years to come. Major advantages to the civilian economy may accrue through either low level doses (pasteurization) or through the higher level doses (sterilization). Examples of some of both types of potentialities are described in the following paragraphs.

1. New lines of convenience foods.

One of the recent lines of popular food items in the supermarket is the so-called "brown-and-serve" rolls. These are sold in the partially baked condition. When ready for use, they need only be taken from the refrigerator, placed in the oven for a few minutes for browning, and served. The irradiation process makes possible the extension of this concept to "brown-and-serve" chicken, beef, pork, and other roasts. There is the added advantage that, in the interim, they need not be kept in the refrigerator.

2. Improved taste and texture of canned foods.

A large factor contributing to the taste and texture of conventionally canned foods is the long heating required. It is conceivable that heat sterilization can be replaced by radiation sterilization for selected foods, especially the meats. The contents can then be heated to the optimal point, taking into account the subsequent rewarming in the family kitchen.

The same approach can be tried for pasteurized foods. Recent findings showed that the heating time as well as the temperature can be significantly decreased by a prior mild dose of irradiation. The resulting Danish ham (normally distributed under refrigeration) reportedly was considerably improved in quality.

3. Expanded markets.

Most of the protein-deficient and hungry peoples throughout the world are not supported with adequate refrigerated handling facilities. Even if fresh meats are made available from other countries, the distribution away from the sea coast would be difficult. Irradiated raw foods, on the other hand, can be shipped without refrigeration. This raises the humanitarian hope that selected meats and fish can reach destitute peoples thousands of miles inland.

Because of insect infestation, tropical fruits are presently quarantined against entry into many countries. The radiation treatment promises to control the deeply imbedded larvae without damaging the fruit. These fruits will probably be permitted across the quarantine barriers. There is also the possibility that the cold storage life of certain fresh fruits can be lengthened significantly. This will extend their shipping radius and marketing zones.

4. Decreased merchandizing costs.

Radiation pasteurization of pork sausages, bacon, hams, and other meats prolongs the refrigerated shelf-life considerably. This will extend the merchandizing period.

Control of insect damage of cereal products, spices, dried fruits, nuts, dates, and similar commodities may well help even out market fluctuations and reduce storage losses.

The sprouting of potatoes, onions, and garlic can be inhibited, thereby enlarging the time of availability.

It is also conceivable that central preparation of precut irradiated meats will be encouraged at the packing houses. This will diminish the cost for refrigerated facilities and skilled butchering at the retail level.

5. Control of food-borne diseases.

The effectiveness of ionizing radiations in destroying helminths, such as trichina worms in pork, has been established. It is expected that the same order of low level treatment would control flukes in fish. Preliminary pasteurization studies have given successful results with salmonella in eggs. The tubercle bacillus in infected cattle products also appear susceptible to control by reasonable doses of radiation. It appears, therefore, that contributions to the control of food-borne diseases may be expected from the ionizing processing technique.

6. Meeting space travel requirements.

Two essential characteristics of materiel for space travel are reliability and minimal weight. It is envisioned that irradiated foods will play a key role in fulfilling its food requirements. Without the need for refrigeration, high quality irradiated meat items can be provided. Fresh fruits, the shelf-life of which has been extended through irradiation, can be resupplied on a regular basis. Some vegetables may be grown locally in the space habitat as an adjunct to oxygen regeneration.

7. Miscellaneous applications.

Several examples may be cited for the sake of ancillary interest.

It has been reported some liquers can be aged more rapidly through irradiation.

The use of ionizing radiations may reduce the bacterial count in the holds of fishing vessels in much the same fashion as ultraviolet light reduces bacteria in the air. By this means the vessel may be able to fish for extended periods of time and longer distances away from home port.

The location of radiation sources at specific points along quarantine borders may combat the spread of plant diseases. The golden nematode in potatoes grown in certain areas of this country or the fly in fruits grown in others are typical of this class of diseases.

In this connection a series of recent experiments raises the possibility of producing allergen-free foods for sensitive children. Contractions of excised uterine strips from mildly sensitized guinea pigs were observed with irradiated raw skim milk. The contractions decreased with increasing doses of irradiation with maximum at 2.79 megarad. Furthermore, the mean lethal shocking doses for irradiated milk samples when challenged on milk sensitized guinea pigs gave a 31-fold decrease in allergenic biological response. A sample of milk prepared by the simultaneous radiation-distillation process, with fluid replacement to maintain volume, produced a reasonably acceptable product of reduced allergenic response.

XI. UNITED STATES TEAM OF COLLABORATORS

For a period of about 3 years prior to the inception of the Army effort, the Atomic Energy Commission carried the major share of the Governmental support. About $500,000 was expended on the program during this period, excluding the activities directed toward the development of radiation sources per se. In addition, three or four food firms were conducting research programs within their own organizations, and a few allied studies were underway. Altogether, there were about six organizations in this country doing significant work in this field.

Since then the effort has been intensified and has enlisted the cooperation of nearly all of the acknowledged leaders in the field of food preservation, as well as many outstanding technical persons and organizations in such related fields as food technology, physics, chemistry, engineering, and biology.

More than 70 investigative groups have joined the cooperative effort, accounting for more than 75 per cent of the budget. There are two principal reasons for placing such strong emphasis on outside contract work:

a. To assemble the many specialized skills required, wherever they may be found, and capitalize on industrial know-how.

b. To hasten the establishment of a sound, wide national base through broad dissemination of all knowledge pertaining to the program as it is being developed.

Chart 6 shows most of the organizations which have collaborated in the program.

AMERICAN ORGANIZATIONS COLLABORATING WITH THE ARMY

Program Advisory Groups

FDA Industry Adv Comm
HEW Adv Comm on Radn Pres
HEW Adv Comm on Linear Accel
Interdepttl Comm on Radn Pres of Food

Atomic Energy Commission
HEW Food & Drug Admin

Source Development
Applied Radiation Corp
Argonne Cancer Research Hosp
Brookhaven National Lab
Curtiss-Wright Corp
General Atomic
Intermuclear Corp
Oak Ridge School of Reactor Tech
U.S. Atomic Energy Commission
Varian Associates
W.F. & John Barnes Co.

Dosimetry
Bausch & Lomb Co.
Corning Glass Co.
General Mills
Kansas State Univ
Minnesota Mining and Mfg Co
National Bureau of Standards
Stanford Research Institute
U.S. Atomic Energy Commission

Irradiation Services
Applied Radiation Corp
Argonne National Lab
Cook Electric Co
Dugway Proving Ground
General Atomic
General Electric Co
High Voltage Engr Corp
Oak Ridge National Lab
Phillips Petroleum Co
Savannah River Facility
Stanford Research Inst
W.F. & John Barnes Co

Radioactivity
Argonne National Lab
Michael Reese Hosp
Nuclear Science & Engr Corp
Savannah River Facility
Stanford Research Inst
University of California
University of Chicago
U.S. Atomic Energy Commission

Microbiology
American Can Co
American Cyanamid Co
American Meat Inst Found
Continental Can Co
Food Research Inst
International Salt Co
Michigan State University
Massachusetts Inst of Tech
National Canners Assn
Syracuse University
Stanford Research Inst
University of Chicago

Mechanism of Quality Losses
American Meat Inst Found
Armour Research Found
Columbia University
Cornell University
Florida State University
General Electric Co
General Institute
Lab of Vitamin Tech, Inc
Massachusetts Inst of Tech
Midwest Research Inst
Ohio State University
Oregon State College
Penn State University
Southern Research Inst
Southwest Research Inst
Stanford Research Inst
Swift & Co
University of California
University of Kentucky
University of Massachusetts
University of Michigan
University of Wisconsin

Phobescence
Alabama Polytechnic Inst
Armour Research Found
Columbia University
Cornell University
Georgia Coastal Plain Expt Sta
Hazelton Lab
Hektoen Inst
John Hopkins Univ
Massachusetts Inst of Tech
Medical College of Virginia
Oregon State College
St Louis University
Syracuse Univ Res Inst
Texas Agr Expt Sta
University of California
University of Colorado
University of Illinois
University of Michigan
University of Miami
University of Rochester
U.S. Food & Drug Admin
Vanderbilt University
Virginia Agr Expt Sta
Wisconsin Alumni Res Found

Product Development
American Meat Inst Found
American Can Co
American Crystal Sugar Co
Anaheim Cold Storage, Inc
Armour and Co
California Packing Co
Carnation Milk Co
Denver, Rio Grande & Western RR Co
Doughnut Corp of America
Fishery Tech Lab
Florida State University
Food Machinery & Chemical Corp
Long Island Vegetable Res Farm
McCormick & Co, Inc
National Dairy Products Corp
Oregon State College
Pillsbury Mills, Inc
Quaker Oats Co

Product Development (Cont'd)
Reynolds Packing Co
Stokely - Van Camp, Inc
Sunkist Growers
Swift & Co
University of California
University of Illinois
University of Kentucky
University of Michigan
U.S. Fish & Wildlife
USDA Plant Industry Sta
USDA Western Util Res Lab
Utah State Agr Expt Sta
West Virginia Pulp & Paper Co

Packaging Development
American Can Co
Continental Can Co
Crown Zellerbach Corp
Dobell & Richardson, Inc
Michigan State University
Monsanto Chemical Corp
National Bureau of Standards
Rhinelander Paper Co
Southern Research Inst
Sutherland Paper Co

Process Engineering
Arthur D. Little, Inc
Food Machinery & Chemical Corp
General Food Corp
Irradiated Products, Inc
U.S. Atomic Energy Comm
W.F. & John Barnes Co

Economic Analysis
A&P Studies, Inc
Arthur D. Little, Inc
North American Aviation, Inc
U.S. Dept of Commerce

Information Services
Office of Tech Info, Commerce
Oak Ridge Tech Info Off, AEC

XII. RESEARCH IN FOREIGN COUNTRIES

At this time, the United States holds undisputed world leadership in this segment of the President's Atoms-for-Peace Program.

Other countries have been showing accelerated interest in recent years. Some countries are making significant progress.

Great Britain has carried on a program on a smaller but very competent scale for about 4 years. She has emphasized low level irradiation applications. Wholesomeness studies, fundamental chemical investigations, product surveys, and process development have commanded the chief attention. An irradiation facility using spent fuel elements from materials testing reactors is in use. The current total activity is a megacurie and will build up to twice this amount in time. The material to be irradiated is in water-tight aluminum cylindrical containers. Another plant is under construction for cobalt-60. Automatic handling will be provided for dose ranges of 0.01 to 5.0 megarads. 2.5 megarads can be given to 200 cubic feet of material per day. The source is 150,000 curies in strength.

Russia has been surveying the application of ionizing radiation to sprout inhibition, meat preservation, grain deinfestation, aging of alcoholic beverages, and inactivation of the silkworm in cocoons. It is understood that wholesomeness clearance for the sale of irradiated potatoes has been given in Russia. Reports have been received on the construction of irradiation facilities scheduled during this year. One facility with a source strength of 100,000 "gram equivalent of Ra" will be used for destruction of insects in grain. Another cobalt-60 at twice this strength will be used for other investigations.

Australia recently announced its entry into food irradiation research. The Australian's HIFAR reactor will provide the required fuel elements. With eight 40-day elements the intensity in the exposure area would approximate 400,000 r per hr.

France has been pressing the low level radiation treatment of fresh fruits, along with a general survey

of the various potential applications of ionizing radiations. An industrial concern has been organized for the specific purpose of commercializing the process. It is pursuing the objective with vigor in collaboration with the French Atomic Energy Commission. A small cobalt-60 source as well as channels in a reactor giving up to 200,000 r per hr are available. Another cobalt source of 3,000 c is being planned for later augmentation to 40,000 c.

Germany has also inaugurated a program with two very competent research teams. The first experiments are underway on survey of irradiation potentialities in various foods, as well as wholesomeness testing in animals.

Poland has been carrying out preliminary experiments during the past year. Studies on potato sprout inhibition were begun last autumn using 200-kv X-rays. More experiments are being contemplated using a 6,500 c cobalt-60 source. Irradiation is also being pursued as a means of suppressing B. coli organisms in milk in order to depress gas formation in subsequent cheese production. Plans are underway for preventing the germination and mildewing of malt and potatoes in connection with extending the period of operation of distilleries and availability of animal food from that source.

Austrian interests are primarily in the area of short-term preservation. The research by groups being currently organized will commence with low level heat treatments in combination with irradiation, with subsequent cool storage of processed foods.

Belgian organizations have been carrying on limited studies with meat, vegetables, and cereal products. Plans are underway to study the pasteurization of grapes and other fruits of economic importance in Belgian agriculture. At the same time, basic research has been also in progress for some time on radiological and enzymic mechanisms, as well as nutritional studies.

Denmark has been carrying on studies involving cobalt-60 since 1957, although studies had been carried on prior to that time using sources in other countries. Pork, chicken products, marine products, and eggs are being surveyed. Since fish, bacon, ham, and pork products comprise their principal food exports, these commodities are receiving particular attention.

Yugoslavia has research underway on the temporary preservation of agricultural crops.

Norway has been carrying out research on a small scale for a number of years, particularly on fish. The same picture holds generally for Sweden and the Netherlands.

Italy has drawn fairly extensive plans for entry into the field in the near future. A newly organized commercial concern is now in existance to develop a practical process.

Greece is interested in the program, although actual experiments have not yet been initiated. Similarly, Iceland is showing considerable interest in the possibility of fish preservation. The same kind of preliminary planning is underway in India, South Africa, Costa Rica, Argentina, and Japan.

52249 O—60—pt. 1——13

XIII. PROGRESS TO DATE

To provide a sense of perspective in evaluating the rate of progress made on radiation processing of foods in the past ten years, it may be of interest to recall the invention of canning by Nicolas Appert in 1809.

No logical explanation could be advanced for what was accomplished through trial and error by Appert at the time. It was half a century later, about 1860, that the causes of food spoilage came to be understood as a result of Pasteur's work. It was another 40 years before Pasteur's theories were specifically applied to the canning industry. Sizeable production began in this country only toward the end of the last century, following the invention of the closed steam pressure retort in 1874.

The following paragraphs of this section describe the progress which has been made in food irradiation, much of which has been due directly to Army stimulation and support.

1. General conduct of the program.

The original aim was to develop the processing of foods by ionizing energy. The military objective was to devise subsistence items of improved quality for troops in combat requiring decreased logistical support. The lead time was to be reduced to the practicable minimum. At the same time, the program was to comprise an important segment of the President's Atoms-for-Peace Program. The United States was to lead the world at all times in technical progress and be the first nation to bring about the implementation of this process on a practical scale so that all mankind would benefit at an early date.

The program was to be carried out on an unclassified basis, with the widest practicable dissemination of information to the public. Most of the research was to be carried out by contract to outside organizations.

Our analysis of the approach was as follows:

a. The immediate practical target would be the first procurement of a sizeable quantity of several militarily important irradiated foods by means of specifications in open commercial bidding.

b. To attain this goal, three minimum prerequisites must be met. These are:

A sufficiently large body of basic data on the nature and availability of irradiation sources, geometry of exposures of food, radiosusceptibility of biological chemicals and organisms, taste and flavor changes induced by radiation in various foods, mechanism of these changes and general approaches toward their inhibition, packaging, and processing engineering factors.

A demonstration of the nontoxicity of irradiated foods, leading to approval by The Surgeon General and the Food and Drug Administration for public sale.

A pilot plant, providing a demonstration of the feasibility of the process, the order of magnitude of costs, and the basis of the military specification for irradiated foods.

In order to make the most rapid progress toward the realization of these goals, it was decided to adopt the following bases of action:

a. Inasmuch as progress on the various answers ride on each other, a parallel attack on the essential work phases was to be launched, taking into consideration the estimated lead times required for convergence at the time of first procurement for military use.

b. Work phases were to be telescoped wherever feasible, as well as multi-purpose facilities provided to eliminate administrative delays involved in separate and consecutive actions.

c. Pending the availability of proper sources of neutron-free radiations with adequate food-processing auxiliary support, available make-shift radiation sources and facilities were to be used to get the project underway as soon as possible.

d. Because of the strangeness and apprehension of "radioactivity" in the minds of people, the wholesomeness program was to be given special emphasis and care.

e. Because of the necessary integration of various technologies, scientific disciplines and viewpoints, a broad dissemination of information to and education of various cadres of peoples was to be attempted.

f. At the same time, a "division of labor" of the various work phases among different government agencies was to be followed as the latter became interested and qualified to pursue the civilian applications to permit the Army to concentrate on its military objectives.

g. Finally, concepts and specific instances of military applications were to be developed in consonance with the advancing technical state of the art and integrated into military subsistence doctrine and use as warranted.

2. Sources of energy.

A wealth of experience has been developed in the design, handling, geometry, and use of sources of ionizing radiation. The Army was the first, for example, to receive a license from the Atomic Energy Commission for the shipment of fuel elements. The use of fuel elements in air has been demonstrated. The Savannah River fuel elements have been put to effective use. Meaningful designs of megacurie sources of radioisotopes and gamma producing reactors have been advanced. As a result of our entry into the field of large radioactive sources, the world is talking about the development of such sources with increasing confidence. Designs of high-capacity, low-cost electron generators, have made great progress. These activities have provided a broad base of knowledge regarding sources, which is a prerequisite to the introduction of purchase specifications into the open market.

The linac and HIFI portions of the deferred U. S. Army Ionizing Radiation Center, then, had not only been intended to serve as sources for the pilot plant scaleup, but also as neutron-free sources for continued research. The presently available fuel elements, small cobalt-60 sources, and rented electron generators are serving adequately as temporary expedients.

Precise descriptions cannot be outlined at this time on the desired characteristics of efficient pilot plant sources. None has been built to date and several yea

of operating experience on perhaps several types of radiation sources will be needed before specifications on the "ideal" pilot plant can be drawn. Nevertheless, extensive studies have been made; several experimental stations have been in use with outputs approaching the order of magnitude of pilot plants; an actual design for a large pilot plant has been completed; engineering and construction have been partially completed on two of its important components. From this experience we can set forth certain considerations about the nature of large scale food irradiation sources.

The food industry is being geared gradually into a more or less continuous flow process from the agricultural field to the processing plant in which the sequence of cleaning, washing, preparation, cutting, formulating, canning, retorting, packaging, storing, and shipping is carried out mechanically. It is not envisioned that the introduction of irradiation will drastically affect this production line, in which considerable capital has been invested. It may be that some specially designed auxiliary equipment may be required, such as new types of conveyors within the exposure chamber, health physics monitors, and food packaging films. But these will not affect the major portion of the plant materially.

From a commercial standpoint, anywhere from 300 to 3,000 lb per hr may be considered pilot plant scale, the data from which may constitute reasonable bases for extrapolation to production engineering. Since the smallest food production line in standard commercial factories has an output of about 3,000 lb per hr, the optimal pilot plant for irradiation experience should approach this value. For sprout inhibition this amounts to about 3,000 x 8,000 rads or 24 megarad-lb per hr; for meat sterilization as much as 3,000 x 4.5 megarads or 13,500 megarad-lb per hr. Assuming reasonable efficiency in the generation and use of radiation, these outputs call for the initial source strength of 100 watts to 40 kw in the case of electron generators and of 10 kc to 4 megacuries in the case of gamma emitting isotopes, such as cobalt-60.

From the various sources examined so far, serious consideration has been given to linear accelerators, specially designed gamma-producing reactors, and cobalt-60 as the most promising production sources of ionizing radiations. These three sources will be described in more detail after a brief mention of each of the other possibilities.

Some of the pioneering research on radiation processing of food has been carried out with the Capacitron. The Electronized Chemical Corporation had an experimental model in operation in 1946. It was an impulse type generator. The original model fired microsecond bursts with energies of 5,000 to 400,000 rads each. More recent tests with a 3-mev Capacitron gave microsecond bursts delivering millions of rads per discharge.

Should future research show that the time-intensity factor is very important in controlling undesirable changes in the exposed food and extremely short bursts of energy are significantly helpful, the Capacitron type of source may become important. In the meantime, however, it has not made as rapid industrial progress as some of the others. As a result, it is not being regarded seriously as an ideal pilot plant source at this time.

The resonant transformer is a far more reliable machine. It has been used extensively for many years as a source of X-rays in ranges up to 2 mev. Several models are available up to 3-mev peak and 8-ma tube current. The resonant transformer has been used in food irradiation research for several years with considerable success. Some machines of this kind are in commercial use for irradiating films and wirings. It has been in operation for long periods of time without significant failures. The beam output has proven quite even, within a per cent fluctuation.

There are reservations, however, about the resonant transformer as a high energy, large capacity pilot plant source. The corresponding increase in size would make it too unwieldy. As a result, it has remained in the category of a larger scale laboratory device and has not yet graduated into the pilot plant stage.

The Van de Graaff Generator has been popular for decades. It has been a standard apparatus particularly in nuclear, semi-conductor, and other research. Commercially available machines come in several models. The more powerful ones which have been used in food irradiation research with good results provided up to 3 kw of 3 mev of electrons. Experimental generators of much higher capacity have also been built.

Theoretically, the charge and hence the potential of the Van de Graaff Generator can be raised to any desired level. However, there are practical difficulties. One is the prevention of leakage from the conductor through

the supports or the surrounding air. Another is the increased insulation required. The resulting machine would be rather cumbersome. As a result, the Van de Graaff Generator has not been highly recommended for the production processing of food. It has proven quite efficient, however, for commercial sterilization of medical supplies, in which the energies and wattages required are not as high.

As nuclear power began to make progress, the profitable use of the radioactive products from reactor wastes became the subject of attention. The question as to whether certain long-lived radioisotopes can be recovered from the wastes and used in food irradiation has been seriously considered. Cesium-137 is one of the more frequently discussed.

Cesium-137 has a halflife of 30 years. It emits a 0.662-mev gamma and 0.51- and 1.17-mev betas. Preliminary studies have shown that the chloride salt can be packed into stainless steel tubes to a density of about 2.6 g per cc and a specific activity of about 25 curies per g. If available in megacurie amounts, such a source would be relatively simple to maintain and operate.

Various irradiation cells using cesium-137 have been conceptually designed. In one case, the cesium chloride is contained in 86 stainless steel tubes, 1.125 inches in diameter and 9 feet long. This provides an initial gamma power of 28.2 kw and a total activity of 7.8 megacuries. They are held on a horizontal plaque 14 feet wide and cooled by flowing water. The irradiation tubes are transported in a shipping casket, which is kept on the bottom of a protective pool when not in use. The tubes are loaded manually from the casket to the source conveyor, which then moves the tubes into place in the exposure chamber. The food packages are carried by 3 parallel belts, each capable of accomodating baskets of sufficient size for 2 V-3 boxes. Four passes before the plaque are traversed by these packages following a safety labyrinth before exit.

Future availability and cost of cesium-137 cannot be guaranteed at this time. Preliminary estimates reveal that a burnup of about 800 lb of uranium will be needed to produce a by-product of 1 megacurie of the radioisotope. This would require a year of continuous operation of a 1,000 MW reactor. At the same time, large separation plants for the recovery of cesium-137 are not yet in operation. The pre-

sent facilities show an annual production of 200,000 curies.

For these reasons, cesium-137 has remained only as a possibility. It is not being advanced seriously at this time as a pilot plant source. It may be reconsidered in a decade. An additional comment may be pertinent with regard to the relatively long halflife involved. Offhand, the long halflife of 30 years appears as an advantage. However, this may not be a blessing entirely. During the early phases of a pioneering technology, an investor may not wish to commit his capital on a long-term amortization in the face of rapid obsolescence of the early prototypes. Only after the technology is well developed and the various production sources are adequately tested would a conservative food processor invest sizeable capital into such a long-lived source as cesium-137.

The homogeneous reactor has been suggested as a potential dual purpose source of heat and ionizing energy. In this type of reactor the fuel is a slurry or solution, which is circulated through the reactor vessel, heat exchanger, cleanup, and makeup systems. There are several places from which ionizing energy can be tapped. The most intense would probably be the circulating fuel itself. However, this continues to emit neutrons, which may bring about undesirable levels of induced radioactivity in the exposed foods. Another source would be the solid fission products, which are continually removed in the chemical processing loop. A third involves the radioactive fission gases, which ordinarily are bled onto a charcoal bed. Of the radioisotopes formed, the gases xenon and krypton appear most readily available. These short-lived gamma-emitting isotopes make up about a third of the energy from the fission gases. They provide about 2 megacuries of gamma rays in a 10 MW homogeneous reactor.

Although about 40 per cent of all fission products are gases at one time or another, the methods of extracting them have not been worked out fully. There are quite a few technical problems to be overcome. The very short halflives of the most active gases, in the order of 7 to 17 seconds, require the development of very rapid methods of extraction from the fuel solution. The hydrogen and oxygen produced by the concomitant radiolysis of water need be recombined. The gases have to be dried and pumped into the irradiation facility. Means must be developed for cleaning the conduits of the solid decay products.

In addition to the technical difficulties, suitably

situated homogeneous reactors with the requisite power output are not available in this country. Inasmuch as only about 5 per cent of the fission energy finally emerges as radioactivity, it would not be economical to construct a homogeneous reactor for the sole purpose of providing ionizing fluxes. As a result of these deliberations, the homogeneous reactor has not been considered promising as a production source at this time.

More food has been treated so far with reactor fuel elements than with any other source of ionizing energy. Several types of fuel elements have been used. The principal one has been the Material Testing Reactor elements. Elements providing dose rates as high as 4×10^6 r per hr have been employed for over 5 years. Several arrangements of fuel elements are in use. At the Material Testing Reactor Station, the fuel elements are submerged under 18 feet of water. They are arranged in a grid, each element separated from the other by thin sheets of neutron-absorbing cadium.

A convenient facility using fuel elements in air has been in use for several years at Dugway Proving Ground. It serves a dual purpose of shipping container and treatment chamber for No. 2 and No. 10 cans. The container itself is a cylindrical shield of about 25,000 pounds of lead and steel. Eight fuel elements of the Material Testing Reactor type are arranged longitudinally around a central chamber, through which cans of food are passed through at a predetermined rate. To insure dose uniformity the cans are retated slowly enroute. The temperature is controlled within 2° F, between 15° to 195° F, by means of cooling coils. Four No. 10 cans or six No. 2 cans can be provided 2 megarads per hr.

Several detailed studies have been made regarding the extension of these and other experiences into pilot and production concepts. Several attractive features have been noted in the case of fuel elements. The most striking, of course, is the fact that radiation from fuel elements can be considered as waste products. Therefore, its costs should be relatively low.

Despite this obvious advantage, not much headway has been made in scaling up fuel elements to a production concept. This is due to several problems which first need to be resolved. One is the uncertainty of control over the radiation spectrum and intensity of the fuel elements to be delivered by the reactors operating at the time. These vary considerably, depending upon the

duration of exposure in the reactor and the period following removal from the reactor. Having important and distinct objectives of their own, reactor engineers cannot be expected to schedule their fuel element discharges to meet the precise demands of the dependent food plant. Another obstacle is the bulkiness of the necessary array of fuel elements and the attendant difficulty in insuring dose uniformity to the product being irradiated. A third is the presence of neutrons.

The discussion so far has considered the less promising energy sources. The three which have been seriously considered for pilot plants are the linear accelerator for electrons and the gamma-producing reactor and cobalt-60 for gamma rays. They will now be described.

The most appealing of electron generators for both pilot plant as well as production purposes is the linear accelerator.

Various models of linear accelerators are commercially available. Applied Radiation Corporation, High Voltage Engineering Corporation, Varian Associates, and Metropolitan-Vickers Electrical Company are several industrial manufacturers. The most powerful from the standpoint of wattage output of electrons has been partly designed and built by Varian Associates. Three hundred sixty pulses per second at 140 kv are released into accelerator wave guides. At the same time, the klystron tubes produce high frequency radio waves which are fed properly phased into the wave guides such that the previously bunched electrons ride the crest of the travelling sine wave down the tubes. The emerging electron beam is switched by the 2 magnets alternately into 2 paths, one onto the top, the other up from the bottom of the food package. At the same time, the beam is scanned back and forth across the width of the package being moved through the field. In this way, dose uniformity can be assured. A typical cycling frequency would be 6 times of 60 pulses each per second. Some of the important design parameters are as follows: output of 6,000 megarad-pounds per hour, beam energy range up to 24-mev with variable step control, average beam power of 18 kw, capability of treating containers up to 6 inches think, 16 inches wide, and 20 inches long.

The first reactor designed specifically for the production of gamma rays by the Atomic Energy Commission was the FIR (Food Irradiation Reactor). The specifications were: 6,000 megarad-lb per hr, maximum dwell time of 15 minutes, dosage variation within the irradiated sample of plus or minus 12 per cent, temperature of the irradiation chamber controllable between minus 30 and plus 75° C, packages up to 6 inches thick by 16 inches wide by 20 inches long. These considerations led to a heterogeneous reactor, with fully enriched fuel, light water moderated.

In general, the FIR is simple in design and construction, fairly efficient in operation, uncomplicated in engineering, high in specific activities, and safe. The core resembles that of the Material Testing Reactor. The reactor core is encircled by a 4-inch blanket of indium sulfate solution. This solution is circulated through the blanket, to the gamma-irradiating loop in the separate food treatment chamber and a heat exchanger before being returned to the core area for reactivation. The indium is activated by neutrons deliberately leaked from the core. The resulting radioisotope, with a halflife of 54 minutes, emits a spectrum of gammas mostly from 1 to 2 mev. Covering the indium sulfate blanket is the thermal shield, which consists of 3 inches of stainless clad carbon steel. This is cooled by water flowing down the 0.125 inch annuli on both sides. The entire structure is then submerged in a biological shield. The latter is a water-filled pool, 27 feet deep, 10 feet in diameter, surrounded by concrete 3 to 6 feet thick. The gamma irradiators consist of two drum types primarily for the processing of foods in cans and two slab types for packages of other dimensions and shapes.

Such a source of ionizing radiations has many advantages. It can be turned on and off thereby controlling the production of radioisotopes. The short halflife permits entry into the exposure chamber within a reasonable time after shutdown. The liquid form of the radioactive source makes possible irregularly shaped irradiation templates for experimentation. This allows added flexibility.

Cobalt-60 has served well for over 5 years as a laboratory source. Many of the significant basic findings in the radiation preservation of food have been made using this radioisotope. The strengths of the early research sources were less than 1 kc, although several of the later ones have been rated as high as 15 kc.

A typical 10-kilocurie source consists of two concentric circles of slender rods. These aluminum clad rods are 10 inches long and a quarter inch in diameter. The central hollow irradiation area accommodates a No. 10 can. Another 15-kilocurie source took the form of flat plates.

Although these cobalt-60 sources represent adequate quantities for test tube studies, they are nowhere sufficiently powerful for pilot plants. For a flexible pilot plant for low dose treatments, about 30 kc would be required. For a large pilot plant for sterilization levels, about 2 megacuries are more in line.

A large pilot plant source of cobalt-60, the HIFI (High Intensity Food Irradiator), is being designed by the Atomic Energy Commission. Its performance specifications are approximately as follows: rated output of 6,000 megarad-pounds of food per hr, dose uniformity within plus or minus 10 per cent, temperature of food treatment chamber controllable within the range of minus 20° F to 170° F, dwell time of 70 minutes for 5.0 megarads, and capable of handling No. 10 cans as well as packages 6 inches by 16 inches by 20 inches. To meet these requirements a three-plaque two-pass system was designed, which would be capable of handling food assemblies 40 inches in height. This is equivalent to 3 cartons of No. 10 cans.

The facility is designed for about 2.5 megacuries of cobalt-60, with a specific activity of 26 c per g. The radioisotope is fashioned into strips approximately 0.8 inch wide, 0.050 and 0.100 inch thick, and 10 inches long. The nickel-plated activated strips are then clad in stainless steel and transported in 15-ton shipping casks, with a cavity 15 by 24 by 38 inches in dimensions, fit into a special railroad flat freight car. The strips are finally arranged into plaques with the desired geometry at the irradiation site. When not in use, the cobalt-60 plaques are stored submerged in the protective canal.

3. Dosimetry.

The Atomic Energy Commission's program on reactors had emphasized the development of low level dosimeters. Inasmuch as the health physics of workers in atomic energy plants had been the principal reason for radiation monitoring devices, less effort was devoted to the accurate measurement of higher orders of magnitude of gamma radiation fluxes. With the advent of the food irradiation progra

it became necessary to develop better techniques for high level dosimetry. Several types of devices were needed.

The first is the primary national standard against which all other dosimeters are to be calibrated. This standard is to be developed and maintained by the National Bureau of Standards. The Bureau has accepted the responsibility and laid plans toward its development.

Satisfactory dosimetry standards and continuous production monitoring systems for electron beam and gamma sources have been developed for use in the range from 0.04 to 10 megarads at rates up to 50 megarads per minute. The methods exhibit energy independence (0.3 to 3 mev for gamma sources, 1 to 50 mev for electron beam sources), satisfactory performance at processing area temperatures, stability, and simplicity for use by semi-technical personnel. Only 4 out of the 18 integrating dosimeters chosen for experimental evaluation came close to meeting these requirements, and none of these alone was capable of covering the dose range. As a result, a pair of dosimeters was adopted. These were the cobalt F-0621 glass for the lower range and the ceric sulfate aqueous solution for the megarad range. These secondary working standards have been further refined and the procedures developed to the point where they can now be used in a production operation. The use of generally accepted standards has eliminated much of the earlier discrepancies in results reported from various laboratories.

Continuous beam current and energy monitors have been developed for use with electron accelerators. The current monitors are based on measurement of low energy secondary electrons emitted from the surface of a metallic foil in vacuo through which the total beam is transmitted. In addition, two energy monitoring techniques have been adapted to suit differing circumstances. One technique utilizes a stack of aluminum foils or plates, each of which is insulated from its neighbors. The second technique is designed for scanned beam accelerators in situations where the first technique cannot easily be applied. Both of these techniques are to be used in conjunction with a beam current monitor.

The continuous gamma source monitor is a spherical graphite cavity ionization chamber designed for operation at dose rates as high as 10 megarads per hr.

Attention has also been devoted toward developing

a reliable, cheap, expendable, and simple dosimeter which can be read without auxiliary equipment and by technically untrained personnel. Total inspection of the processed batch can be achieved by use of such a dosimeter attached to each food package. Go-no-go dosimeter tape has been utilized for several years in the program. The color change, however, is not as distinct as had been expected and there exists also the problem of color fading after irradiation.

Recently, a specially prepared liquid plastic, which undergoes gelphase polymerization upon exposure to the amount of radiation for which it was designed, has shown promise as a go-no-go dosimeter system. The gelation occurs as the result of extensive cross-linking and takes place suddenly upon administration of the predetermined dose. The dosimeter may be prepared in various convenient sizes and shapes.

The liquid plastic dosimeter has been developed to the point of measuring accurately a dose of 10 megarads. At present, it appears that the best solution is to seal the liquid in small gelatin capsules, a regular pharmaceutical procedure. Three different gelatin capsules are then put together in a water-proofed polyethylene container. For example, if the dosimeter is to be made for a desired dose of 4.5 megarads, one capsule would be designed to polymerize a few per cent below 4.5 megarads, one at 4.5 megarads, while the third capsule would polymerize a few per cent above 4.5 megarads. Thus the movement of the liquid plastic solution in its gelatin capsules indicates to within a few per cent the dose delivered to the package. Although further work is needed on this system before it can be used in production control, it appears quite promising.

4. Biological action of ionizing energy.

Even before the Army's entry into the food irradiation program, a wealth of knowledge has been accumulated on the effect of ionizing radiations on insects, helminths, protozoa, fungi, and bacteria.

Several hundred papers have been published on insects alone. It has been observed that low doses of ionizing energy often fail to cause immediate death within a given developmental stage. Instead, the same practical results of insect control can be realized by producing a failure of the insect to pass properly to the next stage. This may occur as death in the process of moulting or complete failure to moult at all, followed by the slow debilitation,

Irradiated eggs may develop into nonviable larvae. Reproduction process may be disrupted, such as the failure of ovaries to develop. The longevity of adult insects is usually reduced when the level of radiation is sublethal. Food intake seems to diminish. It has also been shown that radiation interferes directly with the mechanism of mitosis. The stage of development in which the insect is exposed influences the degree of response. The median lethal dose for eggs of Habrobracon in metaphase I, for example, is about 460 r; that for eggs in prophase I is about 11,800 r. Moreover, cells in the process of differentiation show a higher resistance to the radiation than do cells in mitosis. Finally, it has been found that the composition of the ambient gases during irradiation affects the degree of injury suffered by the insect.

Not nearly as much work has been carried out on helminths, although sufficient basic data are available to enable the formulation of specific approaches toward the control of tapeworms, flukes, and trichina. The best work has been carried out with trichina. Early experiments with rats infected with Trichinella larvae and exposed to 250 r X-rays a day up to 2500 r showed that the number of larvae encysting in the muscle decreased with increase in radiation dosage. Apparently, fewer of the larvae encysted in the muscle and were able to develop to adults, mate, and give rise to viable invasive larvae. Disablement of the larvae to cling to the intestinal mucosa was noted when exposed to over 12,000 r from cesium-137. At 18,300 r the larvae practically disappeared from the intestine. Even before this injury shows itself, however, the larvae have been sterilized by the lower doses. About 3,500 r of X-rays in vitro sterilize most maturing parasites.

Protozoa exhibit varying responses to radiation. Observed changes taking place in the morphological and behavioral pattern of irradiated protozoa are: acceleration and retardation of movement, immobilization, prevention of the mating reaction, reduction of the rate of reproduction, shrinkage of some cells, enlargement of others, enlargement of the nucleus, vacuolization, chromosomal and nuclear disruption, and disintegration and death of the cell. Depending upon the dosage used and the particular species involved, death may occur within a few hours after exposure, after considerable periods but without cell division, at or shortly after the first division, or after several divisions following the sexual process. The resistance of protozoa to ionizing energy is affected by the media as well as the physical conditions. Lecithin and cholesterol are two examples of chemicals which exert an influence. For

example, Paramecium aurelia suspended in a medium containing 1 part of lecithin to 600 parts of culture fluid resisted up to 3.5 times the normal amount of X-rays required to bring about death.

As a rule fungi are much more susceptible to ionizing rays than bacteria. In many cases there is as much as a ten-fold difference in radiosusceptibility. A considerable amount of studies has been carried on fungi of special interest, such as those growing on cured meats and on citrus in cold storage. Most of the work on the fundamental reactions of microorganisms have been directed toward the more resistant bacteria. The subsequent paragraphs will be devoted to bacteria alone, inasmuch as the same general patterns of reactions have been observed for fungi.

The mechanism of bacterial cell injury by ionizing energy is still far from settled. There are two principal schools of thought. One is based on the premise that the free radicals and ions formed by the primary action of the radiation on water are the lethal agents acting on the bacteria. The other school maintains that the radiation brings about a direct ionization within the microorganisms. The resolution of the problem is proceeding in many laboratories. Though of interest to the Army's program, it has not received much financial support to date.

Instead, the money has been directed more toward the study of the various conditions which affect the survival of microorganisms in irradiated foods. The number of organisms present, the pH of the media, the oxygen concentration, the temperature, and the presence of protective as well as sensitizing chemicals, have been investigated. Much research has been and is being conducted on these issues, quite apart from the Army's food program. The accumulated data is voluminous and published liberally in the literature. There is no point in repeating them here.

However, it will be of interest to present some of the more significant results obtained from activities directly supported under this program. Inasmuch as Clostridium botulinum is among the most radioresistant of food spoilage microorganisms, as well as being one of the most toxic, it has been singled out for special attention. Some of the research highlights are presented below.

Several years ago, a sterilizing level of 2 megarads was generally accepted. Because of the extremely poisonous nature of the toxin of C. botulinum, however, bacteriologists have presently adopted the precautionarily high sterilization level of 4.5 megarads for unheated nonacid foods. More work is necessary to decide what the "true" sterilization level should be for commercial practice. Naturally, the lower the dose, the more desirable it would be both from the standpoint of economics and minimal adverse effects on the food itself.

Studies which led to a reappraisal of the sterilizing dose and the need to raise the level originally established showed that spores of bacteria were more resistant to radiation than vegetative cells and that considerable difference in radiation resistance existed not only between the different species but within types from a single species.

The radioresistance of a mixture of 10 different strains of C. botulinum, Types A and B, have also been studied in six different foods. Differences have been noted in the resistance of the strains in the mixture. The resistance of the mixture is greater than that of C. botulinum 62A, a member of the mixture. The response is influenced by the composition of the food media, as well as the temperature during irradiation.

It has been noted that factors influencing the radioresistance of spores of C. botulinum are the same ones that influence their response to heat. Examples of these are initial concentration, the irradiation environment, and the recovery environment.

Meat from unswollen cans of ground beef, which had been inoculated with spores of C. botulinum and stored for several years after irradiation and heat processing experiments, is being tested for the presence of botulinum toxin and ungerminated spores. Cans are selected at random from groups that received approximately the minimum sterilization dose. The minimum sterilization dose is defined for any particular experiment as that dose at which none of the cans processed at that or any higher dosage swelled during subsequent incubation. In any instance where cans remain unswollen from groups that received just less than the sterilizing dose, these also are examined. So far, no toxin has been found and no evidence of ungerminated spores remaining viable has been obtained from the cans examined.

52249 O—60—pt. 1——14

No effect of the extent of heat shock or of treatment time was noted when a level of 700,000 rads was used. It may be that such a difference is apparent only with higher levels. There was a significant difference in the radioresistance of spores in doubly distilled water and in phosphate buffer ranging from 0.067 to 1 M at pH 7.0.

Preliminary data indicated no great influence of pH between 3.0 to 9.0.

5. Wholesomeness.

The most ambitious food wholesomeness clearance program in the history of food development has been successfully initiated and carried on to date. This included the assembling of many teams throughout the country and the establishment of agreements with the Department of Health, Education and Welfare; the Department of the Army; several advisory committees, and open scientific meetings on the protocol and interpretation of results. Considering the usual vicissitudes and difficulties characteristic of such work, even on a small scale performed in private where data can be analyzed in quiet reasonableness, the results on wholesomeness have proceeded satisfactorily.

So far, 8 areas have been or are being studied. These are (a) short term feeding for sub-acute toxicity, (b) long term feeding to evaluate normal physiological activities of dogs, rats, and monkeys, (c) nutritional evaluations of the processed foods, (d) carcinogencity observations, (e) blood and tissue enzyme experiments at the cellular level, (f) histological examinations of tissues from animals of long term feeding experiments, (g) human feeding studies, and (h) special areas of research.

The sub-acute toxicity studies have been completed and the results were uniformly negative in all 44 representatives from all food classes. These data were extrapolated to permit a total of 108 foods of similar types for human taste testing.

The long term animal feeding studies are about 90 per cent complete and all will be completed by September 1960. Although most of the data show no major differences between irradiated and nonirradiated, there have been some data which need further clarification.

From the long term animal feeding studies and a study specially designed to evaluate the nutritional adequacy of foods preserved by ionizing radiation, it appears that vitamin loss is comparable to that observed in heat processing of the same foods. No difference in metabolizable energy value or biological value of proteins in rats on short term feeding studies have been detected to date with the exception of improved digestibility of soya and certain other products.

There have been 3 general types of studies to explore possible neoplastic predispositions. These studies involve (a) the feeding, injection, and skin painting of mice with irradiated extracts from high sterol foods, (b) the accumulation and examination of tissues from animals in the long term feeding program, and (c) special feeding studies of mixed diets of irradiated foods.

Of the second type one study has progressed far enough to comment on. Tissues from rats on the long term feeding studies were examined for 3 types of lesions, namely: neoplasms in the subcutaneous tissues, breast, kidney and urinary bladder; calculi in the kidney, ureter and urinary bladder; and the appearance of a typical vacuolated cell in the pancreas. None of these findings can be correlated with the consumption of irradiated dietary.

One of the studies to explore potential neoplastic predisposition in mice on a dietary comprised of pork loin, chicken, evaporated milk, and carrots irradiated at 5.6 megarads is more than half way completed. So far, no difference in tumor incidences has been reported. Several other studies are underway.

Several types of enzyme studies have been and are continuing to be conducted. These may be separated into (a) those related to changes in blood enzyme systems of rats subsisted on a dietary of irradiated pork, shrimp, green beans, and bread, (b) the determination of possible alteration of digestive enzyme activity due to irradiation

of substrate and/or animals consuming dietaries of irradiated food, and (c) changes in liver enzyme systems.

Of the blood enzyme studies, it has been established that erythocyte transketolase and serum transaminase are reduced in a 12-week period in rats fed irradiated pork. This alteration was judged to be due to the decreased level of thiamine and pyridoxine in the irradiated food.

When macronutrients were irradiated and then subjected to in vitro digestion by purified digestive enzymes, there was little effect on the digestibility of carbohydrate; improved digestibility of undenatured proteins for those proteinases normally acting only on denatured protein, and depressed digestibility of fats by alimentary lipase. Storage of the irradiated substrates showed no effect. A parallel study was conducted on digestive enzymes, namely to feed the animals on irradiated dietaries and then measure the activity of the enzymes of the intestinal tract of the animal so subsisted. Rats were given dietaries of 79 per cent solids of equal parts of shrimp and orange. The shrimp had been exposed to 5.6 megarads and oranges to 0.30 megarad . After 36 weeks the animals were sacrificed. In vitro determinations were then made of the activity of the following intestinal enzymes: esterase, transaminases, monoamine oxidase, peptidase, sacrase, alkaline phosphatase, and glucuronidase. Rats on the irradiated dietary appeared to have somewhat lower enzyme activity in some cases than did rats on the non-irradiated dietaries.

Two types of liver enzyme studies are being conducted. It has been demonstrated that irradiated beef stored at -20° C or at 37° C for 3 weeks, then frozen, when compounded with micronutrients and macronutrients known to be necessary to prepare a dietary equivalent to a standard purified diet, is equivalent to the stored frozen non-irradiated counterpart in maintaining the activity of the following enzymes: rhodanase, glucose-6-monophosphatase, cyanide sensitive and cyanide resistant alkaline phosphatase. Omission of vitamin K from a non-irradiated dietary and the prevention of coprography in the rat results in a cytochrome oxidase activity equal to that of rats on the irradiated beef diet. This is reasonable in the light of the relationship of vitamin K to liver cytochrome oxidase.

Seven human volunteer feeding studies have been conducted. Four involved foods which were held in frozen storage following irradiation. In these studies the quantities of treated food consumed was increased from 35 to 65 to 80 to 95 per cent of the daily caloric intake. There have been 3 studies in which the foods were stored at 70° F post-irradiation. The first of these contained only pork as the treated item. The storage periods in both instances were 90 days and more from the time of treatment to the start of the study. In the latter two studies, the treated foods made up 80 per cent of the daily caloric intake. In summary, 63 foods have been evaluated, 44 in the first four studies, 1 in the fifth, and 18 in the last two. In each of these studies exhaustive clinical and laboratory examination was made of each subject before, during, and after the consumption of the test items. Test periods were of 15 days' duration.

The results of these studies have been consistent. There was no evidence of any untoward physiological nature.

Two animal studies of special physiological importance are still under investigation. The first of these is concerned with the occurrence of a hemorrhagic syndrome in male rats fed irradiated beef in accordance with a special diet compounding. Diets of irradiated beef stored at room temperatures and then fed to rats resulted in hemorrhagic diathesis. It has further been discovered that the disease can be induced in the rat by other dietary practices involving nonirradiated food.

Concurrent study showed that feeding of cooked pork diets of the special type mentioned above resulted in death of both the control nonirradiated and the test irradiated diet groups. There was also increased prothrombin times. Notably, the administration of vitamin K under any of the dietary regimen prevented the rise in prothrombin time. Finally, this syndrome did not occur in animals on a dietary compounded to approach the Military "A" ration, in which a single item such as beef does not predominate as in the other test diets, and which was irradiated and

fed to rats. Although the animals did not grow as rapidly as their mates on the nonirradiated counterpart, the administration of thiamine and pyridoxine eliminated the difficulties.

As little as 4 micrograms of vitamin K per day seem to protect against the observed syndrome. This suggests that the disease is not the result of impaired absorption from the intestinal tract nor from the development of an anti-K factor. It was found that n-decylaldehyde also produced the syndrome. This compound has a carbonyl grouping, similar to those occurring in irradiated beef. It apparently causes the rat's feces to be no longer as acceptable to the animal, which ceases to practice coprophagy. Since feces is a source of vitamin K for the rat, it may be that ionizing energy produces a carbonyl compound that induces the same response.

The extensive feeding tests involving thousands of several species of animals have been in progress for over 5 years. Representative foods exposed to as high as 6 megarads of gamma rays from reactor fuel elements have been fed to animals and human volunteers. None of the foods showed any adverse effects in the acute 6-week animal feeding tests. No adverse effects were observed in human volunteers on 2-week continuous diets up to 95 per cent irradiated foods. Nor has there been any untoward reactions from the thousands of individuals who have sampled irradiated foods.

The long-term animal feeding tests extending over several generations are nearing completion. Growth, feed efficiency, reproduction, and other gross observations have been made. Histopathological examinations of organs and tissues will be made during the coming 3 years. As far as these long term feeding studies are concerned, the results have been encouraging on the whole. Several preliminary observations, such as differences in reproduction in dogs, have been made, which require further verification and analysis. The data at this point are inconclusive and it would be premature to attempt a definitive conclusion. It is estimated that approximately 3 years of additional research will be required to satisfy these questions. About 5 years will probably be required before this food processing technique can be unequivocally approved.

6. Radioactivity.

Determination of radioactivity induced in food and its container is complicated by the fact that all foods contain

measurable amounts of radioactivity. The activity is due principally to naturally occurring radioisotopes, such as potassium-40. The amounts vary considerably with geographical location.

As a result of studies during the last 5 years, the question of radioactivity in foods has been brought within the framework of specificity. Generalities have been pin-pointed. It is now feasible to come into direct confrontation with the issue as far as the radiation preservation of foods is concerned. A summary of present knowledge on foods exposed to fuel elements, electrons, and cobalt-60 are given in this section, together with a comparison with radioactivity encountered under normal situations.

A problem as far as the possibility of induced radioactivity is concerned may be expected from the use of relatively fresh reactor fuel elements. Neutrons are generated during the use of fresh reactor fuel elements in water canals. This is primarily due to the interaction of photons with energies above 2.2 mev with the small amount of deuterium found in ordinary water. Under these conditions (the source of irradiated foods for animal feeding wholesomeness tests), theoretical calculations indicate a level of about 10,000 neutrons per cm per sec.

The neutron flux in most of the sources used in the food program have been measured and tabulated. The fluxes in various sources were: 167 neutrons per sq cm per sec at Argonne, about 7 at Dugway Proving Ground, and 1400 at the Material Testing Reactor. About 50,000 have been estimated for the Savannah River Facility.

Cans of food have been irradiated in all these sources and attempts made to measure radioactivity before and after irradiation. The foods selected were bacon, beef, chicken, green beans, oysters, peaches, and rockfish. However, the natural radioactivity occurring in foods so greatly overshadowed any activity that might have been induced that precise determinations of minute differences in small samples were difficult.

Theoretically, electrons with energies above 2.2 mev induce radioactivity in many elements normally present in food. Below 9 mev, the halflife of the product is in the order of minutes or seconds. The question arises as to the maximum energy threshold which can be considered safe in the practical use of electrons. Many experimental studies have been conducted in pursuit of the answer.

Utilizing beef as the main research medium, it was found that the only activities resulting from the use of electrons above 10 mev which were measurable were those identified to be from carbon-11 and sodium-22. No activity was detected, however, without first using an artificial loading technique, whereby a food sample was "enriched" with large amounts of the element of interest. In the case of beef, sodium nitrate was added to a sodium concentration of 1 part in 72.

Two typical measurements which illustrate the type of results obtained are presented below. When small samples of beef, pork, chicken, and green beans were exposed to 3 megarads of 24-mev electrons, no induced radioactivity was detected in the food. With foods artificially loaded with different salts before exposure, followed by back extrapolation to natural foods, the maximum values of various isotopes in beef range from 10^{-8} to 10^{-10} mc per g.

As far as cobalt-60 is concerned, theoretical calculations suggest that induced radioactivity should not be a problem. This has been confirmed by actual experiments. Cobalt-60 irradiation of 24 elements commonly occurring in food gave no detectable radioactivity. Similarly, beef exposed to 20 megarads did not emit a single beta emanation over a period of hours. Even "salting" with heavy concentrations prior to irradiation would not produce radioactivity detectable by any known technique, according to theoretical calculations.

Work is continuing on the study of radioactivity in foods. More facts will be accumulated, so as to place the question of what constitutes safe thresholds in proper perspective. At the present time, cobalt-60 appears to be considered "safe" by all experts in the field. The use of electrons awaits further clarification. A few comparative figures are given below to indicate the quantitative magnitudes under consideration with regard to electrons.

The maximum permissible level of Na^{22} in food for continuous human consumption, according to National Bureau of Standards Handbook No. 52, is 8,810 disintegrations per minute. This is compared to a value of 0.16 disintegrations, calculated to be the level induced in food from experiments using artificial heavy "salting" and subjected to 5 megarads of 24-mev electrons.

Certain chemical additives officially approved as safe in commercial practice add as much as 10^{-6} mc of radioactivity per g of food, as a result of the potassium-40 isotope contained therein.

Whole body radiation to man living in a brick house is 104 mr per year, as compared to 50 mr per year in a wooden house. The average from a radium dial wristwatch is 40 mr per year. If one were to subsist on a diet of 100 per cent 24-mev electron sterilized foods, he would receive a whole body dose of 0.26 mr per year. This, of course, represents the worst possible exposure condition, which is far beyond any intended by the Army for human consumption.

7. Sensory evaluation methods.

During the early days of the program there was much disagreement concerning the reaction of various foods to ionizing energy. The discrepancies were so large among laboratories that it became difficult for neutral observers to evaluate the state of the art. This had led to much unnecessary arguments over taste and odor changes induced by ionizing rays.

There has been considerable progress made in standardizing sensory evaluation techniques. One of the most significant actions in this regard was a series of cooperative comparative studies using a homogeneous beef sample. The study was designed to determine whether the results of sensory evaluations conducted in laboratories in different

parts of the country could be correlated when the starting material and the evaluation method were uniform. Six industrial, three academic, and one government laboratory participated.

The homogeneous beef sample was prepared at one laboratory and also irradiated at one single location. Four dose levels of 0, 1.25, 2.5, and 5 megarads were used as the treatment variable, and samples were maintained frozen at all times until prepared for evaluation at the participating laboratory. Two sensory evaluation methods were suggested for use, and the same procedures were given to each participant. One method was an evaluation of the intensity of irradiation odor/flavor by a "trained" panel. This consists of people who had sufficient experience with radiation-sterilized beef to recognize its characteristic flavor. The other method was the hedonic scale preference by an untrained panel. The latter consists of people who were not familiar with beef treated in this fashion.

Excellent agreement was obtained between laboratories using both methods. In the intensity method, the trained panels indicated that the intensity was a direct, though not linear, function of dose. In the preference method, the untrained panels showed no preference difference among the three lower doses and only the highest dose was significantly less preferred. The study was very successful in insuring a reliable correlation of sensory evaluation results among many laboratories, provided standardized methods and materials are used.

The findings also emphasize the caution which must be made in interpreting reports on sensory evaluation. Although a trained panel is able to distinguish small differences, they may be evaluating a particular component of the total flavor quality, which may not be significant to the "naive" consumer. Further investigations into this area concerning the sensory significance of flavor changes are being carried on.

8. Taste, odor, texture, and appearance of foods.

The significance of changes brought about by ionizing energy must be evaluated against the background of intended use. If one is interested in low-level irradiation for sprout inhibition, insect and trichina control, or even pasteurization, then he would not be too concerned over the capability of the particular food in question to withstand the sterilizing levels. The converse is equally true.

In 1954 little was known as to the chemical and physical effects of ionizing radiation of foods per se, and only limited information was available as to the effect of radiation on the macro or micro-molecular constituents of foods. A general statement that "irradiation causes off-flavors" was not further definable as to its specific effects on products. Consequently, most of the first year's efforts were devoted to a broad survey of the effects of irradiation on whole foods and food components. About a hundred foods have been screened. At the same time, a substantial fundamental research was launched into the mechanism of chemical and physical changes brought about in foods by ionizing particles. Attention has been devoted to two particular questions, namely:

a. What are the chemical and physical changes occurring in the treated foods which affect the sensory quality of the product?

b. What means can be used to prevent, inhibit, or mask these changes so that the most acceptable end products can be produced?

Although the major attention has been devoted to changes induced in whole foods, some interesting results have been obtained on pure compounds or model systems. As far as fundamental research on carbohydrates is concerned, para-magnetic resonance spectra for a number of irradiated crystalline carbohydrates indicated that the final radical produced is the same whether the energy source is soft X-rays or electrons.

G values have been calculated for sucrose, methylglucopyranoside, maltose, and trehalose. Irradiation of aqueous solutions of sorbitol yielded D-glucose, L-glucose, D-arabinose, and L-xylose. Possible mechanisms for these reactions have been described.

Irradiation of glucose solutions produced a trace of arabinose as well as simple carbonyl compounds. Hydrolysis of maltose by electrons was proportional to dose. Glucose was detected in the irradiation product. Hydrolysis of inulin increased with increasing dose. D-Fructose was one product. Hydrolysis of trehalose solution produced some glucose. Hydrolysis of raffinose was non-linear with dose since more than one glucosidic bond was being broken.

Considerable results have also been obtained on the fundamental changes in foods themselves.

In raw meat, the myoglobin is oxidized to oxymyoglobin, even in the absence of oxygen. A red color results. With oxygen present, a brown shade occurs because of the additional conversion of the pigment to the metmyoglobin form. In cooked meat, the main reaction is a reduction of the hemichrome to the hemochrome. This resulted in a bright red cooked meat. Exposure of this red meat to air converts it in a short time to the gray-brown color of cooked meat.

Chemical compounds present in larger amounts following exposure of raw beef are: acetaldehyde, acetone, ammonia, carbon dioxide, dimethyl disulfide, dimethyl sulfide, ethanol, ethylamine, hydrogen sulfide, isobutyl mercaptan, methanol, methylamine, methylethylketone, and methylmercaptan. Hydrogen sulfide, methylmercaptan, and "carbonyls" have been identified in heat enzyme-inactivated radiation-stabilized beef. The significance of any of these compounds to the odor/flavor profile has not yet been firmly established, although there is strong evidence that the sulfur-containing compounds are implicated.

The irradiation flavor of cooked beef has been shown to be mainly volatile. It is absorbed to a large extent on an activated carbon during storage at room temperature. It can also be "stripped" from the non-volatile beef flavor itself by vacuum distillation of a slurry held between 40 and 50° C. In raw beef, however, the irradiation flavor is of low volatility. It is generated from water-soluble non-dializable proteins.

The sequence of protein bonds attacked by ionizing energy appears to be as follows: $-SCH_3$ (most labile), -SH, imidasole, indole, alpha-amine, peptide, and proline. This correlates with studies on proteins which show that the content of sulfur-containing amino acids is directly related to the amount of irradiation odor, and that sulfation of the sulfhydryl, phenol, and hydroxyl groups of a protein inhibits the odor formation. In beef, the quantity of volatile sulfur-containing compounds increases with higher irradiation doses.

The degradation of pectin has been related to the softening of fruits and vegetables. They both occur at about the same irradiation dose. In relation to color, anthocyanins and chlorophylls are bleached to a noticeable extent depending upon the product.

The primary irradiation problem of softening in plant products may turn out to be an advantage in tough-

textured vegetables, such as peas and asparagus. The bleaching of color noted in some plant products may be a problem with items such as strawberries and peas. Other items tend to develop a brownish discoloration in storage due to the radiation-induced degradation of higher carbohydrates to reducing sugars, which subsequently undergo the browning reaction.

As far as the reaction of foods themselves are concerned, the effect of radiation varies, as expected, with dosage. At the lowest levels of irradiation used, such as for sprout inhibition, insect, and helminthic control, most foods react favorably. Cereal bars, for example, withstand 50,000 rads without adverse changes in their acceptability. The same holds true for flour.

The series of studies on potatoes is nearing completion. The optimum dosage for sprout inhibition has been shown to be in the order of 7,500 rads. At this dosage, the potatoes do not rot and there seems to be no serious interference with the desirable wound-healing properties. For optimum results, potatoes should be treated after they have undergone a suitable curing period.

At the pasteurizing level, certain fresh meats and some varieties of fish behave satisfactorily. Cod, flounder, and haddock have been reported to withstand a megarad of exposure without the development of undesirable changes. Considerable loss in color occurred in salmon at 500,000 rads. The storage-life at 35° F of finnan haddie exposed from 0.7 to 1.4 megarads was at least 318 days. The storage life of kippered herring subjected to 0.23 to 1.9 megarads was at least 251 days at 35° F. Clam meats exposed to 0.7 to 0.93 megarads became unacceptable after 116 to 154 days of storage at 35° F. The storage life of clam meats treated with 1.4 megarads was at least 178 days.

Flavor changes are not considered serious in the pasteurization of raw meat. Changes due to discoloration, enzymic, and microbiological action are the major problems. Vacuum-packaged pork cuts and pork sausage in transparent films maintain their normal coloration for longer periods than do beef cuts and hamburgers. Antibiotics augment the effect of irradiation on storage life. Some meat items, such as table-ready meats, develop undesirable flavors even when given a dose of less than 1 megarad. There is some question as to the value of combined antibiotic treatment, inasmuch as

some radiation-pasteurized meats break down enzymically before becoming spoiled microbiologically.

Most fresh fruits are on the borderline. The first signs of softening in apples appear at about 500,000 rads. A blanched sliced apple pie mix, however, with sugar, pectin, cinnamon, and salt added before treatment, withstood even sterilizing levels without adverse changes. The same holds for applesauce. Considerable promise is being shown in the extension of the refrigerated shelf-life of certain fruits, such as plums, apricots, peaches, tomatoes and oranges. There are some indications that higher rates of application of ionizing energy give better results, but they need to be confirmed.

The refrigerated shelf-life of strawberries exposed to about 1.5 megarads was extended 1.75 times. That of blueberries was more than doubled by 0.14 megarad. Sour cherries was improved in flavor by exposure to 1.9 megarads, although color was adversely affected. Refrigerated shelf-life was extended about 3-fold, while the beta carotene content was increased.

Exposure to about 0.19 to 0.37 megarad caused up to a 3-fold extension of refrigerated shelf-life of asparagus. Treatment of snap beans to 0.69 and 1.2 megarads showed extensions of refrigerated shelf-life of about 6 times. The same holds true for blanched lima beans exposed to 0.45 and 0.69 megarad.

At the high sterilizing levels, most foods are not naturally resistant. Lettuce and other leafy vegetables wilt readily. Dairy products give unacceptable off-odors. Pork, chicken, bacon, ham, and shrimp react satisfactorily. Veal, lamb, and beef lie in between.

Not only have flavor changes of individual foods been studied, observations have also been made on prepared foods. The following series of results provides an illustration of the type of work involved.

Beef, pork, and chicken, prepared in gravy and in barbecue sauces were exposed to 3.0 to 5.0 megarads and evaluated for acceptance after 0, 3, and 6 month storage at 70–75° F. Evaluations were made by a "sophisticated" experienced panel, accustomed to detecting and evaluating small flavor differences of the beef products. Only beef and barbecue sauce irradiated at 3.0 megarads were scored "acceptable" initially and after 3 month

storage. Beef stew was "acceptable" up to 5.0 megarads immediately after radiation; however, after storage all products with the above exception were scored "unacceptable" at 3.0 and 5.0 megarads initially and after storage.

The effects of variations in preparation techniques, using isotonic saline and methods of cooking, were studied. It was found that when the saline in which the products were irradiated was discarded and the beef served with a freshly prepared gravy, a better flavor was obtained than with beef irradiated with gravy. No definitive differences resulting from the different methods of cooking could be noted. The use of saline seemed to detract from the desired meaty flavor.

Pork and barbecue sauce at 3.0 megarads was "acceptable" initially and after 3 and 6 month storage. Pork and gravy was "unacceptable" immediately after exposure but after 6 month storage, the samples treated with 3.0 megarad were rated "acceptable".

Chicken in barbecue sauce at 3.0 megarads rated "acceptable" initially and after 3 month storage. Chicken and gravy was "unacceptable" immediately and 3 months after exposure. After 6 months, however, samples treated with 3.0 and 4.0 megarads were "acceptable".

Studies have also been made on spices which are used in foods. Insect infestation can be eliminated in spice products by ionizing radiations. In practically every case, the treated spices showed no evidence of live insects after 3 months incubation. The treatment occurred at levels of 50,000 and 75,000 rads. When exposed to 3 megarads, no significant change in the character of the spice itself occurred, as measured by triangle comparisons using a panel of about 20 members.

None of the spices investigated, when combined in frankfurters and pork sausage and given 3 megarads showed any tendency to mask or prevent ionized flavor and odor significantly. In general, irradiation appears to reduce the odor and flavor of spices in pork sausage.

Various means have been investigated to decrease the undesirable changes in treated foods.

The heat treatment necessary to inactivate enzymes results in a "medium well-done" meat product. The use of a lower range of temperature for a longer period of

time to inactivate enzymes appears to produce a better product with a greater retention of juiciness.

The atmosphere of packaging has been shown to be important, at least in reference to the exclusion of oxygen. Nitrogen, carbon dioxide, or vacuum packing produce better products in regard to flavor, low peroxide values, and vitamin retention. Product temperature, within limits, during irradiation does not appear to be important in respect to the quality of the end item. Irradiation in the frozen state seems to decrease the changes to a certain extent. Activated carbons are moderately effective as odor scavengers. Combination of irradiation with antibiotics is also being tried. Counter current air stream has been found effective in flushing out off-odors generated during the irradiation of liquids. The presence of tomato sauce seems to reduce off-flavors of meat products to a significant degree.

The off-odor of irradiated cooked pork was shown to be due to a large extent to rancidity. It can be significantly decreased by polyphosphates, trihydroxybutyrophenone, green tea extracts, and tomato soup, either alone or in combination with sodium ascorbate.

As a result of aids of this nature, as well as more advanced techniques for controlling the conditions of irradiation, the quality of certain treated foods has been improved considerably during the past 2 years. About 5 years ago, for example, the literature contained frequent references to the so-called "wet dog" flavor of sterilized beef. During the past year, repeated samples of sterilized beef have been produced which have been acceptable to lay test panels. Skilled meat specialists or persons sensitive to "radiation flavor", however, can detect off-flavors.

Acceptable flavor has been obtained in milk sterilized with 2 megarads of gamma rays by concurrent distillation under vacuum. More research is needed, however, to suppress the browning and gelling upon prolonged storage of the sterile product.

The problem of keeping blood-raw sterilized meats at room temperature is aggravated by the action of enzymes. It has been observed that enzymes are relatively much more resistant to ionizing energy than microorganisms. As a result, sterile meat is still

subject to the destructive action of enzymes. Much research has been carried out on the effect of ionizing radiation on enzymic action in foods, as well as possible methods of inhibition. The most practical among the latter is heat blanching, providing a product which still retains the fresh-like quality when prepared for the dinner table. From a military standpoint, objections against the lack of the original bloody raw appearance are not overriding. Nevertheless, it may be so in a civilian market. As a result, work has continued on the nature of enzymic reactions in unblanched irradiated products.

One of the more interesting studies involves the effects of pre- and post-enzyme inactivation storage on irradiated beef and pork roasts. The results indicated that raw irradiated beef and pork can be stored at 76° F for periods up to 16 days prior to enzyme inactivation without adverse effects. Although proteolysis, as measured by the increase in amino nitrogen, occurred as storage of the raw irradiated roasts was prolonged, the increase was not marked until after 8 days. The increased protein breakdown appeared to be responsible for poor acceptability and the mushy texture of roasts held for 32 days storage or longer before enzyme inactivation. This would suggest that even raw beef and pork can be shipped and handled today up to 2 weeks at room temperature without spoilage. This is an important experimental beginning.

From the food technology standpoint, an immediate military target of irradiated "brown-and-serve" large pieces of beef, pork, chicken, and ham which are equal in acceptability to their fresh refrigerated counterparts is now within sight of success. Secondary targets, such as ready-made sandwiches, improved quality "canned foods", fresh fruits with sufficient shelf life to be delivered to troops in active combat areas without refrigeration are being brought into the realm of reasonable expectations.

9. Troop acceptance testing.

About a year ago, a most significant step had been taken in the taste testing of irradiated foods.

Prior to 1958, taste testing was conducted by small panels of 20 men or less, as a rule. These tasters were usually experts to a more or less degree. The food samples were prepared by laboratory personnel. As a

52249 O—60—pt. 1——15

result, the question arose concerning the large scale acceptability of irradiated foods, as compared to their fresh counterparts, by troops fed in military messes with meals prepared by military cooks. Two such tests have been completed.

The first consists of 240 soldiers, half of whom were served the irradiated and the other half the fresh untreated counterpart from the normal refrigerated supply chain. The irradiated samples tested were: pork stored at room temperatures for 10 months and prepared as barbecue and as roasts, and bacon stored at room temperatures for 12 months and oven fried. No significant difference between the taste ratings for the irradiated samples and for the fresh controls was observed.

The second test involved about the same number of troops. The foods in this case were: stew and parts from sterilized chicken stored for 9 months at room temperatures, sterilized shrimp for 15 months, sterilized carrots for 15 months, and pasteurized pineapple jam and fruit compote for 12 months. Response on the part of participants indicated that, with the exception of carrots, the irradiated items were as acceptable as the fresh controls.

10. Packaging.

While some work had been accomplished on the effects of high levels of radiation on packaging materials per se in the past, the matter of proper packaging for irradiated foods was largely unexplored 4 years ago. Attention first had to be given to determining what materials could safely be used.

Early experiments suggested that the metal can would meet the minimum requirements with the least amount of study, modification, or time.

Doses above 60 megarads damage steel, resulting in dislocations, thermal spikes, and embrittlement. However, at dosages up to 6 megarads, the effects are negligible.

Investigations to date indicate that ionizing energy at the levels of interest has no influence in promoting the rhombic-cubic transition of tin. This is of importance since many foods may be irradiated at temperatures below the critical point of 18° C.

These and other experiments have shown that the presently used steel alloys and tin coating weights are satis-

factory materials for containers. This conclusion is based on work involving string beans, cherries, beef, chili, fish, pork, and on less precise data from studies on several other foods. Information from these representative foods, when compared with data from thermally processed foods, gives no indication that unusual problems will arise.

With the exception of formulations of butyl rubber, commercial end-sealing compounds are actually toughened and improved by irradiation. The butyl rubbers are depolymerized and unsuited for the purpose. Of thousands of cans of food which have been treated there has been no record to date of can failure attributable to the nonbutyl compounds.

Commercial interior enamels have been found satisfactory, except for oleoresinous enamels, which are not suitable for foods with high percentages of free fatty acids. Oleoresinous enamels can, however, be used for enzyme-inactivated foods. Other enamels can be substituted for foods high in free fatty acids.

The ideal shape of containers for uniformity of dose distribution and efficiency of energy utilization is rectangular. Commercial rectangular cans are available in sizes ranging from 6-oz sardine cans to 12-oz luncheon meat cans and 6-lb pullman cans, up to dimensions of 11 inches by 16 inches by 5 inches.

Initially, it was felt that solution of the enamel compound problems with tin plate cans would be an automatic solution to these same problems in aluminum cans. The original premise is still valid. However, a difficulty of adequate bonding of the enamel has been observed in experiments with thermally processed foods in aluminum cans. A series of studies are planned to investigate this question, as well as the difference in shelf life between irradiated foods contained in aluminum versus tin plate cans.

Flexible containers, which have been in use for only about 20 years, have presented many problems in their utilization for frozen and refrigerated foods. They were, therefore, expected to pose difficulties for irradiated foods. However, it was felt that attempts to surmount these problems should be made in view of the potential savings in cube and weight, as well as greater efficiency in the irradiation process itself.

At 1 megarad or less, ionizing energy has no significant effect on the physical characteristics of plastic packages. Some materials are slightly affected at 2 megarads. Films such as trifluoromonochlorethylene, saran, pliofilm, and cellulose show embrittlement above 3 megarads. However, even at 6 megarads the physical properties of Mylar, polyethylene, vinyl, polystyrene, and nylon remain unaffected.

During the irradiation of plastic packages containing various foods, it was found that salad oil promoted the delamination of polyethylene combinations to a slightly greater degree than in unirradiated packages. In some cases the radiation induced changes in the food increased the adverse effect on the packages. The latter was usually small and generally of little importance.

In the course of this work, certain defects were observed which were the result of food-package interactions independent of irradiation.

The major problem encountered is the development of stress-cracking, attributable in some degree to fatty acids and fats contained in the food. This has been overcome by use of a material known as Scotchpak. The latter has demonstrated remarkable resistance to food, food acids, and fats during irradiation and subsequent storage.

In regard to adverse effects by the package on foods, the same principles apply as far as the control of color changes during storage of irradiated and of refrigerated and frozen foods. Off-colors have been observed, but these were corrected by proper package selection. A significant problem area was uncovered, in that irradiation of some plastics results in the formation of odorous substances, which diffuse into the food. Recently, however, Videne was found to develop practically no odor or flavor during irradiation, and nylon and polystyrene were also very low in odor formation. The principal troublesome individual of the promising films has been polyethylene. In this case the odor and flavor principals exist prior to the irradiation, which appears to intensify them.

Microorganisms are capable of penetrating thin films. This is usually due to microscopic openings which may be inherent in the films, resulting from rough handling, or damage introduced during sealing. One way of overcoming this is by increasing the thickness of the package and using improved sealing techniques. With thicker films, rough handling did not promote penetration of microorganisms

Although the final flexible film package has not yet been developed, sufficient basic data are now available to begin its formulation. In all probability it will be a laminate of about 3 layers. This should require about 2 years for completion. In the meantime, the metal can serves adequately for experimental items.

11. Economic analysis.

Periodic economic analyses have been conducted. Two series have been completed so far.

The first was a general analysis of broad possibilities, before embarking on the program. This was completed in 1953, which led to the activation of the Army's program.

The second series consisted of much more detailed economic and logistical study after the accumulation of more technical data resulting from several years of laboratory research.

The economic analyses have been undertaken by various agencies. Generally, these attempts had been handicapped by the lack of actual large scale food irradiation experience and firm costs for large sources of radiation. The cost estimates for the unit plant operation of irradiation clustered around a figure of 3 cents per lb of sterilized beef in production. Electron accelerators have been estimated to be cheaper, below a cent per lb. Costs for lower level irradiation are correspondingly less. Trichinosis control, for example, has been estimated at around 10 cents per ton of pork using a production linear accelerator. For grain irradiation on a large scale preliminary calculations suggest that cobalt-60 is slightly cheaper than fumigation at current costs.

Based on technical data available in 1956, one typical study estimated the cost of 2.5 megarad treatment of foods by various sources of radiation as follows: Spent fuel elements 2.05 cents, gaseous fission products 0.36, separated cesium-137 (excluding cesium cost) 0.38, sodium-24 0.65, reactor activated indium 1.40, 7.5-kw electron accelerator 0.55, 50-kv electron accelerator 0.24.

It is expected, of course, that the costs will decrease as technology and volume demands increases. It has been estimated that at electron outputs of tens of kw per installation, costs would range from 1 to 10 dollars per kwh. If hundreds of kw are used in a single installation the costs should be 10 cents or less per kwh. For cobalt-60 there is an estimated three-fold decrease from 3 cents per

lb at a throughput of 100 lb to 1 cent at a throughput of 10,000 lb.

As technological improvements are made, the cost of capital equipment, which represents a major investment, will also decrease significantly. Over a period of 10 years, from 1947 to 1957, the capital cost of electron generators dropped from over $350,000 to about $60,000 per kw. Similarly, the quoted price of cobalt-60 dropped from over $5 to less than $1 per c.

From the standpoint of military logistics, it appears that the extra processing costs are outweighed by anticipated savings resulting from decreased refrigeration requirements. What additional savings can be realized from other considerations such as decreased volume of the rectangular food packages in lieu of round cans, food spoilage in the combat theater, and discards from food monotony and forced feedings would render the economic picture more favorable.

The overall conclusion from the studies so far is that the process is economically feasible and that costs will decrease with time.

12. Concepts of military use.

The specific way in which irradiated foods are to be used in the combat theater is determined by a careful integration of many considerations. Among the more important are the following:

a. The strategic and tactical concepts of warfare adopted for the time frame under consideration.

b. The current technical state of the art as far as irradiated foods are concerned.

c. The current technical state of the art as far as other types of subsistence commodities are concerned.

d. The practical "departures from the text-book norm" as far as wartime military subsistence is concerned, based on actual experience from previous conflicts and extrapolation into possible future ones.

Throughout the program on food irradiation, the Quartermaster Corps, in cooperation with CONARC, has maintained a balanced posture in developing concepts of militar

use. It has kept a theoretical concept for experimental planning purposes up to date. It was recognized that the particular model serves only as an interim point of reference to guide the research to a higher order of specificity, which in turn leads to a more specific military concept of use. The approach also included concept testing of various combat feeding systems at the Combat Development Experimental Center and at various maneuvers, such as Hardcore. At the same time, the lessons gained from these troop exercises were combined with the latest laboratory results on irradiated foods and the prediction of the tactics envisioned in force at the time frame when irradiated foods are expected to be available.

So far, there have been three stages in the evaluation of our concept of military use. Each is progressively more specific. It is envisioned that with two more versions, precise descriptions of the end-items to be made available to troops can be given. In the meantime it would be of interest to describe the past progress toward the present state of thinking.

Prior to the initiation of the program in 1954, a general analysis of the military requirements have been made. It took into account many of the considerations in Section IX. The favorable outcome of the study led to activation of the current program.

After several years of intensive laboratory research, the practical potentialities of the process became more definitive. At the same time the logistic demands of the modern Army began to emerge. Based on these advances, a second schematic concept of military use was adopted for further research planning and tactical examination. This was presented to the Army Policy Council in 1957. It is shown in Chart 7.

The upper half of the chart outlines the main components of the prevailing feeding system. The lower half does the same for the new system.

The components of then current system were:

a. The A-ration, consisting of fresh foods and prepared by trained cooks, is fed in the Support Area whenever conditions permit. As a rule, however, the modified B-ration is used. This consists of canned goods but supplemented with fresh meats and vegetables.

ARMY COMBAT FEEDING SYSTEMS (1957)

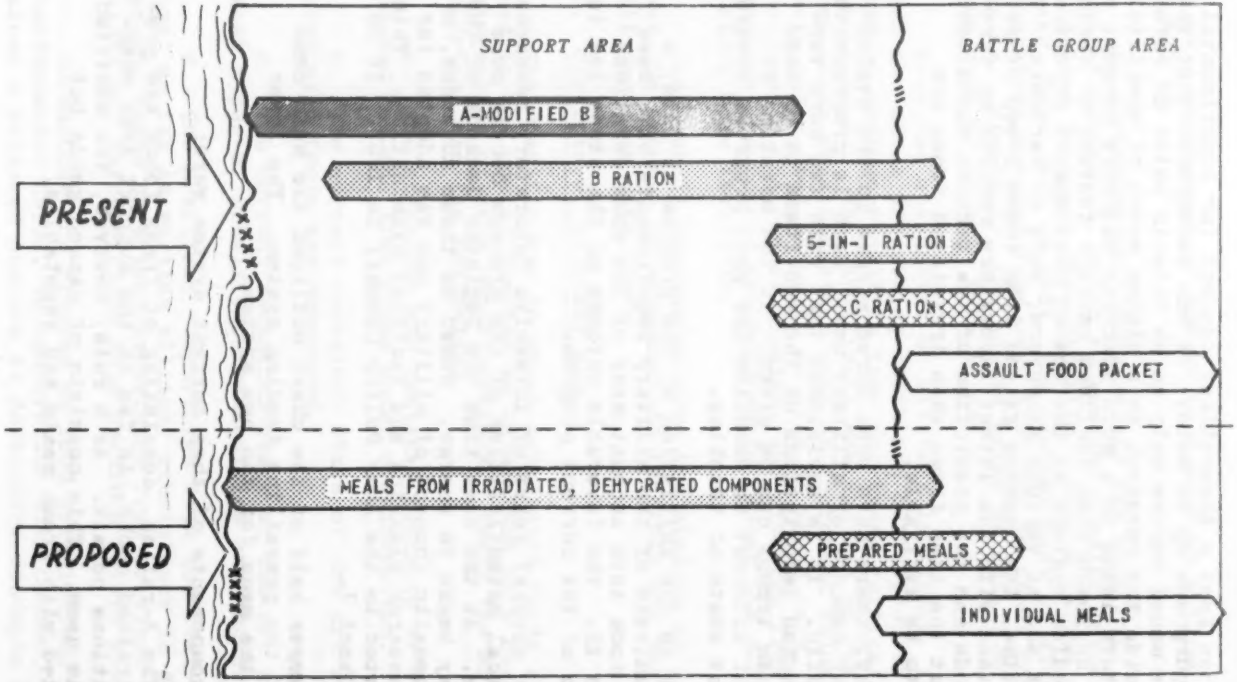


Chart 7

b. The straight B-ration consisting completely of canned foods and other non-perishables, is used for feeding large groups. This requires cooking personnel and equipment but no refrigeration.

c. The 5-in-1 ration, for feeding tank crews and other small isolated groups, resembles the B-ration in composition. Some cooking equipment is necessary.

d. The C-ration for feeding one individual for one day consists of canned goods and other non-perishables. Only minor cooking equipment is required.

e. The assault packet is not a complete meal. Three of these, then, do not fulfill a day's nutritional requirement. But it does provide sufficient sustenance for an individual soldier performing such activities as patrol, and combat during the assault phases.

There were several places in such a feeding system in which significant improvement was required.

First, some refrigeration facilities are necessary if troops are to be indefinitely sustained on an adequate diet in the Support Area. Something should be done to reduce this refrigeration load and yet provide an adequate amount of highly acceptable foods.

Second, trained cooks are required even within the forward companies. In tune with the streamlined modern Army, this cadre of trained support personnel in forward areas should be drastically reduced.

Third, meal preparation equipment is needed with the B-ration and the 5-in-1 ration even into the battle group area forward. To increase troop mobility, the reduction of this paraphernalia is highly desirable.

The schematic approach to gain these improvements without sacrificing the quality of our meals is outlined in the lower half of the chart. The proposed feeding system is based on a minimum provision of two hot meals per day.

In the battle group area forward, group and individual prepared meals will be served. These will not require trained cooks, nor the standard cooking equipment, nor a long preparation for hot meals.

Trained Cooks
Minor Preparation Equipment
None

In the Support Area and the balance of the theater, what corresponds to our present A and/or modified B-rations will be served. This will not require refrigeration facilities.

By such a division of feeding zones, two distinct varieties of menus are offered in the theater. The fact that the style of cooking in the rear area is different from that in the forward area will contribute greatly in rebuilding the morale and esprit of our troops when they are rotated for rest or recuperation.

The nature of meals in the new feeding system is as follows:

First, meals from irradiated and dehydrated components. These meals are descendants of the present B-ration. They are intended for use in the rear area. They consist of uncooked foods preserved by dehydration and/or irradiation. The overall result would be hot meals approaching the A-ration in acceptability, but requiring no refrigerated handling of fresh meats and other perishables.

A typical dinner will consist of orange juice, lima bean soup and crackers, fried chicken, sweet potatoes and green beans, rolls and margarine, coffee, and apple slices.

Three dehydrated components, namely, orange juice, lima bean soup and green beans, and the irradiated chicken have made this particular meal possible. Other items on the research menu include irradiated pork chops, beef steaks, and ham.

Second, prepared meals. These are precooked and dehydrated in Continental United States and assembled in various combinations and quantities to fit the using combat unit of 5 to 1,000 men. These meals will be used, as the situation dictates, anywhere in the combat zone, but especially in the more forward areas, where mess preparation facilities are limited or non-existent. The design is such that hot meals can be prepared by men with no food service training. All that is required is the addition of boiling water to the food in its shipping container, allow it to stand for 15 minutes, and serve.

A typical luncheon consists of fruit mix, chili and beans, instant rice, bread, margarine, jam, cocoa, and

cookies using disposable eating utensils. Other precooked dehydrated entrees on the research menu include chicken and rice, spaghetti and meat sauce, and ground beef.

Third, individual meals. These are designed for use by individuals in active combat. Irradiation techniques make possible a variety and quality of items never before attainable in a ration for use under such extreme conditions. These are to be eaten cold, except for hot beverages.

A typical dinner meal consists of orange slices, fried chicken parts, bread and pecan rolls with jam and margarine, coffee and milk.

This conceptual scheme advanced in 1957 provided a good reference chart for the development not only of irradiated but also dehydrated and other types of subsistence commodities. It integrated the total food research and development effort active at that time. After further progress in research, two specific combat meals utilizing irradiated foods were included in the 1958 Army Combat Developments Objectives Guide. These are:

"Meal, Uncooked, 25-Man. A ration, factory assembled and packaged by meals, for a 25-man module, which will simplify field preparation, have reduced weight and volume, require no refrigeration, and yet be adequate in nutrition and acceptability to maintain the performance of combat forces when fed for an extended period without supplementation by perishables. (Maximum use will be made of preservation by dehydration and ionizing radiation as well as of lightweight packaging materials)."

"Meal, Ready-to-Eat, Individual. Individual meals, ready-to-eat, containing only quick-serve precooked, dehydrated and irradiated components for use up to one week in the combat zone. Components should be highly acceptable when eaten cold. No preparation required. Normal supply of drinking water must be available. Packaging should be lightweight and also suitable for use in place of mess gear."

At the same time a thorough study of the future combat subsistence complex had been initiated in 1956 as the Army Combat Development Study Project QMCCD 56-2. This 3-year analysis has just been completed by the Quartermaster Board, in a draft report entitled, "Subsistence and Food Service for the Army in the Field."

Some of the more pertinent conclusions of the study, which will lead to more definitive stipulations of military requirements, have been described in Appendix B. The study is currently undergoing the usual coordination and review through various Army elements, prior to final adoption. In the meantime, it appears that irradiated foods can be used to great advantage throughout the combat theater, to be incorporated as components in most of the rations envisioned for the future. An artist conception is presented in Chart 8. With this study on hand, the Army will be on a favorable basis to "tailor-make" irradiated foods into specific commodities for military uses.

13. Coordination with other agencies.

Internationally, a thorough exchange of scientific information has been attained. Members and contractors of the Army have played roles in all international meetings held on irradiated foods in the United States, England, Canada, Poland, Switzerland, Argentina, Holland, and other countries.

Within the Government, the Interdepartmental Committee had been organized and is now functioning smoothly. This followed extensive briefings of the White House staff, Departments of State, Defense, Commerce, Agriculture, and the Atomic Energy Commision. The Army held the chairmanship for the initial 2 years.

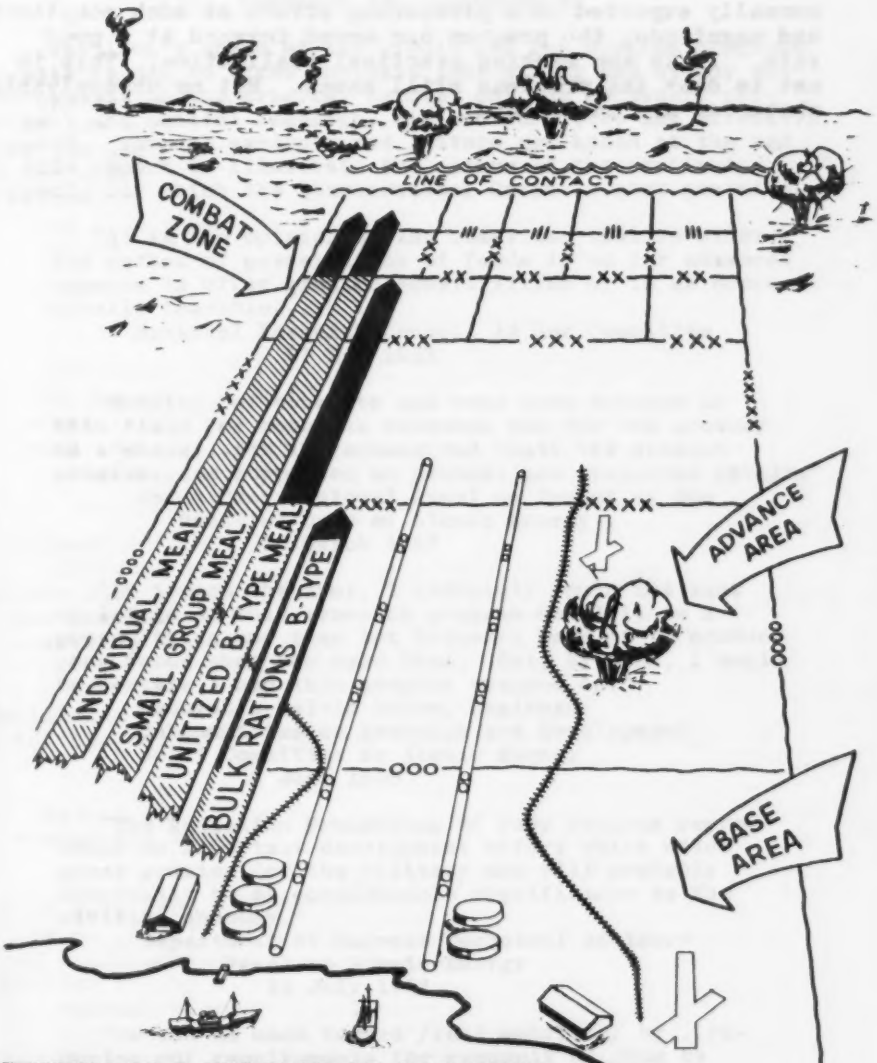
Particularly smooth relationships have been maintained between the Army and the Atomic Energy Commission and the Food and Drug Administration.

The Joint Congressional Committee on Atomic Energy has been kept informed by 2 formal appearances and intermittent reports and communications.

Among the research contractors, all reports even of preliminary and tentative nature, have circulated, so as to keep everyone informed of the latest developments. Periodic meetings have been held in which all active contractors exchange views, comment on, and criticize constructively the various phases of the program.

14. Summary.

The Army has made excellent progress during the past 5 years in food irradiation. Despite the difficulties



FEEDING IN A THEATER OF OPERATION

with area potential maximum utilization of each type ration shown in black

Irradiated items, as they become available, will become a part of each of the above rations

Chart 8

normally expected in a pioneering effort of such complexity and magnitude, the program has moved forward at a good rate. It is approaching practical realization. This is not to deny the problems still ahead. But no unresolvable obstacles are envisioned.

XIV. COMMENTS AND CONCURRENCES

The lion's share of the credit for the program progress to date is due to those who have lent strong and steady encouragement to the program, carried out the necessary persistent and skilful research, and provided wise and effective counsel. Several excerpts and letters are added at the end of this report to illustrate the nature of the continuing support, for which the Quartermaster Corps is most grateful.

"It is the opinion of the Committee that no other new method of preservation of foods is as far advanced, appears to offer greater possibilities or is as economically feasible...."

National Research Council Ad Hoc Committee
27 May 1953

"Nothing but benefits can come from success in this field for both the consumer and for the economy as a whole...(It is recommended that) the present program...be supported at present and projected levels."

Joint Congressional Panel on Impact of the
Peaceful Uses of Atomic Energy
26 March 1955

"If I were the Army, I certainly would not want to let go of this research program until it is a proven thing and then let industry have it to produce your foods when you need them. But, by gosh, I would be certain I had this program wrapped up."

Honorable Melvin Price, Chairman
Subcommittee on Research and Development
Joint Committee on Atomic Energy
8 June 1956

"The Radiation Processing of Food Program represents an important development effort which holds great promise for the military and will probably eventually be of considerable significance to the civilian economy."

Department of Defense Technical Advisory
Panel on Atomic Energy
11 July 1957

"We can do much toward [real mobility] by...reducing our requirements for resupply of food by reducing bulk and weight and increasing its keeping qualities through dehydration and irradiation."

Lt. General Carter B. Magruder
The Program of the Deputy Chief of
Staff for Logistics
1 June 1959

HEADQUARTERS
DEPARTMENT OF THE ARMY
OFFICE OF THE SURGEON GENERAL
Washington 25, D. C.

MEDDH-MR 14 December 1959

SUBJECT: The Revised Program for Irradiated Food

TO: The Quartermaster General
Department of the Army
Washington 25, D. C.

1. The revised program for the development of a method of preserving food by ionizing energy, 1 December 1959, has been reviewed in this Office. The Surgeon General concurs in:

a. The desirability of proceeding with this program, and

b. Those aspects of the program of medical interest requiring medical service participation and collaboration.

2. Approval of this program by appropriate Army authorities is recommended.

/s/ LEONARD D. HEATON
Lt. General, MC, USA
The Surgeon General

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
FOOD AND DRUG ADMINISTRATION
Washington 25, D. C.

November 23, 1959

Joseph H. McNinch, Brigadier General, MC
Commanding, Hdq., U. S. Army Medical R&D Command
Office of The Surgeon General
Washington 25, D. C.

Dear General McNinch:

This is response to your telephoned request for further comments on your letter of November 2. Please consider the following comments as a reply to your letter rather than my letter to you dated Nov. 9.

You are concerned about the data on toxicity and wholesomeness testing with fuel rods as the radiation source, and the applicability of such data to similar studies on foods irradiated with gamma rays from cobalt-60 as the irradiation source and electrons from particle accelerators.

It is our understanding that the maximum dose received by foods in the Irradiated Food Program used for toxicity and wholesomeness testing is six million rads. The remarks given below are based on the premise:

(a) That this dose is the upper limit of treatment under consideration in this letter. Foods treated with doses higher than six million rads will require considerable investigation even up to a complete repetition of the wholesomeness program.

(b) That your investigators are able to measure accurately the equivalent absorbed energy if the food is treated with electrons.

Data on wholesomeness and toxicity of foods treated by the mixed spectrum of radiation from spent fuel rod sources would be applicable to data obtained using foods treated with cobalt-60 as a radiation source, for equal radiation dose absorbed.

The data on wholesomeness and toxicity of foods treated by mixed spectrum of radiations from fuel rod sources would be applicable to foods irradiated with electrons produced by a particle accelerator, provided the maximum energy level of the electrons dose does not exceed 5 Mev.

The use of energy levels above 5 Mev, at the present time, cannot be considered until sufficient experimental data are available upon which to judge the possible problem of induced radioactivity.

Sincerely yours,

/s/ A. J. Lehman, M.D.
Director, Division of Pharmacology
Bureau of Biological and Physical Sciences

52249 O—60—pt. 1——16

UNITED STATES
ATOMIC ENERGY COMMISSION
Washington 25, D. C.

December 11, 1959

Major General A. T. McNamara
The Quartermaster General
Washington 25, D. C.

Dear General McNamara:

The Atomic Energy Commission appreciated the opportunity to review the draft revised Army Program on Food Preservation of Ionizing Energy.

The Commission regards the radiation processing of foods as a particularly important potential application of atomic energy. It is expected that it will ultimately make a substantial contribution to the Atoms-for-Peace Program. In this regard, we believe that approval of the proposed Army program would be in the national interest.

We are pleased to note it is envisioned that the Army's activity will continue to serve as the backbone of the Nation's effort in this program area. We do, however, agree with your plan to concentrate effort on a limited number of items of military significance. The program should be accelerated by thus concentrating available funds and energies. It does not appear that the program which you have proposed will be duplicated by industry or other government agencies.

We wish to endorse the plan for additional irradiation facilities to support the program. The advantages of essentially neutron-free sources are apparent, and the proposal for a flexible cobalt-60 irradiator is believed to be a sound one. In addition to supplying radiation processed foods for research purposes, this irradiator could be used to develop and demonstrate the best and most economic methods of radiation processing of foods under a wide variety of conditions. The cobalt-60 irradiator would also tend to retain focus on the United States as a leader in the field of radiation processing of foods, a factor not to be overlooked from the national viewpoint.

The necessity for a linear accelerator is less apparent, however. It appears that requirements relating to study

of induced radioactivity can probably be fulfilled with existing facilities. With information presently available to us, we could not concur in the need for a linear accelerator at this time.

We note that the unexpended balance from HIFI funds can be applied to facilities for the revised program. The expenditure of these funds for irradiation facilities should greatly benefit the radiation processing of foods program.

As you know, the Interdepartmental Committee on Radiation Preservation of Food has established an Ad Hoc group to formulate a national civilian program for radiation processed foods. We look forward to the Army's cooperation in facilitating the transition of radiation processed foods into the civilian economy.

Sincerely yours,

/s/ A. R. LUEDECKE
General Manager

NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL

ADVISORY BOARD ON QUARTERMASTER RESEARCH AND DEVELOPMENT
of the
Division of Engineering and Industrial Research
2101 Constitution Avenue, Washington 25, D.C.

17 November 1959

Major General C. G. Calloway
Commanding General
Quartermaster Research and
Engineering Command
Natick, Massachusetts

Dear General Calloway:

The National Academy of Sciences - National Research Council, Advisory Board on Quartermaster Research and Development, Committee on Radiation Preservation of Food, of which I am privileged to serve as Chairman, has just completed a searching, critical review of the revised radiation preservation of food program proposed by your Quartermaster Research and Engineering Command.

As a result of this review, our Committee desires to express its unanimous approval of this new program. We reaffirm our confidence in the ultimate military and commercial feasibility of preservation of foods by radiation.

As you know, the Committee on Radiation Preservation of Food has given long, studied, and sustained support to this program.

The program as presented by the Quartermaster Corps is an excellent one, execution of which will require adequate funding. In our opinion the proposed funding as requested should be recognized as minimal.

We feel constrained to express to you that the present plan for a revitalized research program holds this same faith for the future, and please be assured of our desire to support, to the utmost, this challenging effort.

For the Committee,

/s/ Walter M. Urbain
Chairman, Committee on Radiation
Preservation of Food
National Research Council
National Academy of Sciences

FOOD PRESERVATION BY IONIZING ENERGY

DEPARTMENT OF THE ARMY, OFFICE OF THE QUARTERMASTER GENERAL

REVISED ARMY PROGRAM

ON

FOOD PRESERVATION BY IONIZING ENERGY

Approved: 11 March 1960

Department of the Army
Office of The Quartermaster General
Washington 25, D. C.

I. POLICY

Inasmuch as nonmilitary departments are beginning to be in a position of carrying leadership responsibilities for the national Atoms-for-Peace Program in radiation processing of foods, the Army will affect a smooth transition toward focussing on military requirements. Research will be directed toward the objective of procurement from the civilian economy of the first generation of a relatively few food items of important military significance. The developmental lead time will be compressed to the maximum extent feasible, consistent with the state of the art and the requirement for the prior orderly resolution of the key unsolved fundamental research problems. The Army will work closely with industry during the research stage with the objective of facilitating the earliest possible transition to process engineering and production.

Inasmuch as the Army's activity will continue to serve as the backbone of the Nation's effort in this program area, generous collaboration will be extended to other organizations in the joint advancement of the President's Atoms-for-Peace Program.

Inasmuch as an adequate civilian production base is required before military subsistence requirements can be met, cooperation with American industry will be encouraged. Furthermore, information will be disseminated as widely as feasible in order to increase technical know-how in this country.

II. SIX-YEAR OBJECTIVES

1. To obtain wholesomeness clearances permitting unrestricted use of foods preserved by ionizing energy.

2. To conduct the necessary basic research to advance the technology of food radiation processing so that items of military significance and of quality far superior to analogous items available in the combat theatre can be procured:

   a. Primary emphasis to be placed on high dose treated (sterilized) pork, smoked ham, chicken, and beef.

   b. Secondary emphasis to be placed on those low dose treated (pasteurized) items of special military significance.

3. To conduct timely economic analyses.

4. To formulate such items into logistic-saving components for use in Army ration systems from those in the support areas to and including individual military feeding in the forward areas.

5. To develop components meeting special requirements of the Navy, Air Force, and Marines.

6. To develop process engineering data for efficient transition into industrial sponsorship.

7. To determine, within the coming 3 years, whether the transition pilot-production plant will be built by industry, the Atomic Energy Commission, the Army or another organization, and to effect the necessary transfer of relevant know-how.

8. To establish a reservoir of basic information for future improvement of radiation processed foods.

III. RESEARCH AND ENGINEERING PHASES

The program will be channelled essentially into the following tasks: Military applications and economic analysis, Assurance of wholesomeness, Pre and Post Irradiation Studies, Destruction of microorganisms, Nuclear effects on foods, Acceptance testing, and Packaging studies.

Prime interest will be focussed on four sterilized meats and their combat ration formulations. Secondary attention will be devoted to low dose treatment (pasteurization) of fresh fruits of high morale value. A description of the seven tasks is given below. The starting point in each of these tasks is the present state of the art. At the same time, they have been pointed directly toward the immediate six-year military objectives, delineated in Section II.

1. Military applications and economic analysis.

Attention will be devoted toward completing a comprehensive operations analysis to determine the logistic, operational and economic aspects of incorporating radiation processed foods into the combat feeding system of the armed forces. The studies will consider both limited and general warfare. Comparisons will be made between foods preserved by radiation and by other processes, together with the respective roles to be played by each in the optimum overall combat feeding system.

2. Assurance of wholesomeness.

This phase will continue to be directed by The Surgeon General and logistically supported by the Quartermaster Corps. The protocol under which the work is to be continued has been developed with full cooperation and concurrence of the Food and Drug Administration. It has been designed to result in clearances for unrestricted consumption of radiation processed foods by both military and civilian populations. Included are six principal sub-phases, namely:

a. Short term feeding to animals, principally rats, which has been completed.

b. Long term feeding of 21 representative foods to each of 2 species of animals for 2 years, followed by comprehensive histopathological examinations. The feeding work is 90 per cent completed. The tissue evaluations, which will be done by the Armed Forces Institute of Pathology, are currently in progress.

c. Carcinogenicity and enzyme studies which are approximately 50 per cent completed.

d. The resolution of several experimental anomalies, which have been noted in long-term animal feeding. These will require effort beyond that already in progress. Additional work in two areas, possible sterility in dogs and possible auricular rupture in mice, may extend over a period of 3 years.

e. Additional new work with regard to the biological aspects of possibly induced radioactivity.

f. Human feeding studies. Those conducted for evaluation of acceptability of radiation processed foods have been deferred pending the determination of residual induced radioactivity. It appears that the tests may be resumed in the not too distant future. Long-term human feeding will await adequate resolution of the animal anomalies and conclusive information on induced radioactivity.

3. Pre and Post Irradiation Studies

Efforts will be directed toward meeting requirements of field Army feeding. Usable sterilized beef, pork, chicken, and ham items in the individual combat meal and small group operational rations will be developed in accordance with Combat Developments Objectives Guide. In addition, the use of these prime conponents, either sterilized or pasteurized, as logistic-saving components in A and bulk B rations will be pursued. Morale-significant items, such as fresh fruits, will constitute a tertiary goal.

Processed foods will be studied with regard to their retention of color, flavor, texture, and nutritional quality. Pre-irradiation and post-irradiation factors will be considered, in addition to those acting during the exposure period. Interactions among these factors will also be taken into account.

Pre-irradiation processing treatments which will be investigated will include pre-cooking techniques such as steaming, roasting, broiling, and frying; time, temperature and method of heat application for enzyme inactivation; addition of salts, tenderizers, flavor accentuators, spices, and off-flavor suppressants; headspace composition; and oxygen odor scavengers.

The effects of processing conditions accompanying irradiation will be explored. Among those which may have significant influence on product quality are dose rate, dose fractionation, product temperature, and gaseous exchange.

Among the post-irradiation factors which will be studied are: the influence of residual enzyme activity, cause of excessive softening, time-temperature condition conducive to product improvement,

interactions between various components of formulated products, interaction between food and package, and time-temperature effect on general chemical degradation of stored irradiated foods.

A fundamental research program will be continued to determine the origin of the organoleptic changes, the mechanisms whereby they occur, and means for their control. Initially, this sub-phase will be focussed principally on beef.

Studies will be conducted on identification of chemical changes occurring during the irradiation of meats, and subsequent storage under a variety of time and temperature, dose, dose rate, headspace composition, and additives.* Fractionated meat components and model systems of proteins and lipids will be studied to provide an understanding of the underlying reactions.

Optimum characteristics of odor scavengers, which are effective in "dry" packs, will be established. Further research will be undertaken to develop scavenger systems which can be effectively utilized with "wet" packs.

The mechanism of proteolytic enzyme reaction will be studied, with the hope of improving methods of enzyme control, superior to the present blanching technique.

4. Destruction of microorganisms.

Basic research will be conducted on the physiology and biochemistry of microorganisms with special emphasis on anaerobic spore formers of public health significance. The mechanism of action of ionizing energy on the various stages of development of these microorganisms will be determined.

A clear understanding of the influence of a variety of processing and substrate factors will be sought in order to develop conditions whereby foods can be safely irradiated at substantially lower doses then presently adopted to gain quality and economic advantages. Some of the processing factors will include: dose, dose rate, dwell time, beam spectra, heat-interaction, energy pulsing, and temperature. Some of the substrate factors to be analyzed are: type of food, moisture, pH, strength of inoculum, and chemicals.

Studies to determine the particular types and strains of Clostridium botulinum which are the most radioresistant will be undertaken in order to establish a definitive sterility reference for processing by ionizing energy.

*Usual sense of the term, not legal sense.

5. Nuclear effects on foods.

The pertinent isotopic content of selected foods of interest will be determined by literature analysis and experimentation. Efforts will be expanded to determine the probability and theoretical and measurable amounts of activity induced in actual food items and in food "phantoms" by radioisotope, spent fuel rod, and electron beams of various energies.

A quality control procedure will be developed, which will be used to guarantee radiological safety of treated foods as established by Food and Drug Administration, Public Health, Atomic Energy Commission, and the Army Surgeon General, leading to early resumption of human feedings studies and eventual general acceptance of food so processed.

The above studies will be coordinated with The Surgeon General, particularly with reference to biological interpretations of the resulting data.

6. Acceptance testing.

Troop-feeding tests will be conducted on two levels following approval by and with the collaboration of The Surgeon General. The first, designed to determine acceptability, consists of single meals to about 200 soldiers per test. The second, designed to measure monotony factors and field utilization, will be operated as engineering tests.

An engineering test will be based upon 100,000 meals containing about 5.5 oz of irradiated meat per meal. About 2 to 4 engineering tests per year will be conducted, once the approved irradiated items can be provided.

7. Packaging studies.

Only minor studies will be conducted on tin plate cans, which have been shown to meet minimum requirements as a container for irradiated foods. Extended storage involving aluminum cans will be completed.

Investigations on flexible and semi-rigid containers will be directed toward materials and container research. An evaluation will be made of the nature and amount of extractives and possible induced radioactivity produced in various plastics by the irradiation process. Means of controlling the production of these substances will be sought. Work will be directed toward the development of new laminates with improved resistance to ionizing energy, in addition to the normal attributes of useful containers.

IV. TECHNICAL COORDINATION WITH OTHER ORGANIZATIONS

Within the Army, CONARC, CDEC, and other elements will be consulted in the conduct of operational analyses of irradiated foods in the Army subsistence complex. Additionally, collaboration will be maintained with the Navy, Air Force, and Marine Corps in meeting their special requirements.

Coordination with other government agencies and the Interdepartmental Committee on Radiation Preservation of Foods will be effected. Intimate bilateral working relations will be maintained especially with the Atomic Energy Commission, the Department of Health, Education and Welfare, the Department of Agriculture, the Department of Interior, and the National Bureau of Standards on special work phases of mutual interest.

Advice will be sought from various quasi-governmental bodies, such as the National Research Council.

The major portion of the actual research itself will be conducted by private industry and universities, although irradiation services from central sources will be provided. The plans and results of all workers in the program will be closely coordinated.

V. FACILITIES

Maximum use will be made of facilities available in industrial and academic institutions, in addition to those currently present in government establishments. The state of progress in the program is advancing at such a pace and in such a direction, however, that a moderate research facility is now needed to carry out necessary investigations.

The most desirable source from the standpoint of radio-logical safety is cobalt-60. The availability of such a source as soon as practicable is essential for major advances in the program, particularly in the human feeding phases. At the present time, adequate sources of cobalt-60 are not available. Based on an Army research requirement 2 years hence of about 50 tons of gamma-treated food per year; of a reasonable source time for research on such problems as source geometry, dose distribution in containers of different sizes and shapes, and flux uniformity of radiation field; for use by other Government agencies; and for irradiation services to industrial collaborators, it is estimated that about a megacurie of cobalt-60 will be required.

In order to provide the minimum amount of laboratory support, a small food sampling, preparation, and testing annex will be needed as an adjunct to the gamma facility.

The requirement for a source of electrons at the same location has been carefully considered, in view of the availability of a partially completed linear accelerator. There are good grounds to believe that future costs of commercial processing may favor electrons significantly over radioisotopes for some commodities. Certain treatments, such as restricted surface irradiations, can only be carried out with electrons of specified energies. It is desirable, on this basis, that electrons continue to be investigated.

The actual cost of the needed research facility, currently proposed to be constructed at QM R&D Command, cannot be determined without negotiations with potential contractors. Estimates are as follows: Cobalt-60 Irradiator, (1,000,000 curie) $1,100,000; completion of linear accelerator (12 MEV), $400,000; Food laboratory annex $300,000. Total estimated cost amounts to $1,800,000.

Current analysis indicates that the most suitable location of this research facility is at the Quartermaster Research and Engineering Center at Natick, Mass., where it can be utilized, not only for food research, but for other research requirements of the Army, other DOD elements, and the national civilian radiation foods program. However, a Joint Board will be formed by the Quartermaster General, composed of representatives of agencies most concerned with the location, for the purpose of recommending to the Chief of Research and Development the most appropriate location for the facility.

VI. FUNDING

The required funding is shown in Table I. It is to be noted that the Atomic Energy Commission has an unexpended balance of approximately $2,100,000 as of this date. This money can be applied toward certain phases of the project funding, if approval is granted.

Breakdown of the figures follow the work phases described in Section III. The last entry covers the cost of radiation services furnished the various research contractors. The cost of food for troop testing is not included in this budget.

Table I

RESEARCH AND DEVELOPMENT BUDGET

FISCAL YEAR	61	62	63	64	65	66
Military applications and economic analysis	--	--	--	--	50,000	--
Assurance of wholesomeness	300,000	250,000	200,000	100,000	50,000	50,000
Pre and Post Irradiation Studies	340,000	340,000	340,000	440,000	320,000	250,000
Destruction of microorganism	90,000	80,000	60,000	50,000	25,000	25,000
Nuclear effects on foods	40,000	40,000	40,000	40,000	--	--
Acceptance testing	--	--	--	35,000	60,000	60,000
Packaging studies	50,000	50,000	50,000	100,000	75,000	50,000
Radiation services	180,000	180,000	180,000	180,000	180,000	180,000
TOTAL	1,000,000	940,000	870,000	945,000	760,000	615,000

FACILITY BUDGET FY '61*

Food Preparation Facility	$ 300,000
Electron Accelerator	400,000
Cobalt-60 Irradiator	1,100,000
Total	$1,800,000

*Can be funded from AEC unexpended R&D funds

52249 O—60—pt. 1——17

APPENDIX 2

In response to a request made by Representative Price for copies of the material indicating that irradiated foods may have toxic and pathological effects in animals when ingested over a long period of time, as reported on in January 1959 at meetings of investigators at Highland Park, Ill., the following reports are submitted for inclusion in the record:

Proceedings Contractors' Sixth Annual Meeting, Quartermaster Corps Radiation Preservation of Foods Project—Held at Hotel Moraine-on-the-lake, Highland Park, Ill., January 27–29, 1959.

The Nutritive Value of the Major Nutrients of Irradiated Foods and Appraisal of the Toxicity of Irradiated Foods—Contract No. DA–49–007–MD–544, Progress report No. 15, for period September 21, 1958—March 15, 1959. Division of Animal Nutrition, University of Illinois, Urbana.

Hemorrhagic Syndrome in Rats Fed Irradiated Beef—Contract No. DA–49–007–MD–996, Period: September 1, 1958 to April 1, 1959. Progress report No. 1. St. Louis University School of Medicine, St. Louis 4, Mo.

Mechanism of the Hemorrhagic Phenomenon Produced in Male Rats by Feeding of Irradiated Beef—Progress report No. 2, Contract No: DA–49–007–MD–951. Period: September 15, 1958, to March 15, 1959, Department of Medicine, Medical College of Va.

The Nutritional Adequacy and Probable Toxicity of Foods Preserved by Ionizing Radiations—Progress report No. 12, Contract No. DA–40–007–MD–549. Period: March 15, 1959 to September 15, 1959, by Norman F. Witt, PhD, Chemistry Department, University of Colorado, Boulder, Colo. and U.S. Army Medical Research and Nutrition Laboratory, Fitzsimons Army Hospital, Denver, Colo.

The Nutritional Adequacy and Probable Toxicity of Foods Preserved by Ionizing Radiations—Progress report No. 11, Contract No. DA–49–007–MD–549. Period: September 1, 1958 to March 15, 1959, Chemistry Division, University of Colorado, Boulder, Colo. and U.S. Army Medical Research and Nutrition Laboratory, Fitzsimons Army Hospital, Denver, Colo.

Research To Determine Whether Any Toxic Effects of Protein Quality Changes Are Induced in Dried Whole Egg by Ionizing Radiation.—Semiannual progress report for the period September 14, 1958, to March 15, 1959, Contract DA–49–007–MD–775 with Office of the Surgeon General, by Department of Food Technology, Massachusetts Institute of Technology, Cambridge, Mass.

The Influence of Irradiated Lipids on the Incidence of Spontaneous Mammary Carcinoma and Hepatoma in Strain A/HE and C_3H MICE—Contract research progress report, Contract No. DA–49–007–MD–579, Department of the Army, Office of the Surgeon General, with University of California Department of Physiological Chemistry, Los Angeles, Calif. Period: September 15, 1958, to March 15, 1959.

Effect of Ionized Radiation on the Nutritive Value of Food—Six months report for the period ending March 15, 1959. By Clive M. McCay, Stocking Hall, Cornell University, Ithaca, N.Y.

Gamma-Ray Activity of Quartermaster Bacon Samples—Submitted to Walter Reed Army Institute of Research During August, September, and October, 1959, final report.

A Long-Term Feeding Study on Chicken and Green Beans, a Long-Range Investigation of the Nutrition Properties of Irradiated Food—Progress report V, general progress report XIII. Contract No. DA–49–077–MD–582. Period: September 15, 1958 to March 1, 1959, by L. R. Richardson, Professor of Biochemistry and Nutrition, Texas-Agricultural Experiment Station, College Station, Tex.

Possible Carcinogenicity of Irradiated Foods—Progress report. Period: October 15, 1958, to March 15, 1959, Contract No. DA–49–007–MD–794, by Harry Monsen, University of Illinois, College of Medicine.

PROCEEDINGS

CONTRACTORS' SIXTH ANNUAL MEETING

QUARTERMASTER CORPS

RADIATION PRESERVATION OF FOODS PROJECT

held at

Hotel Moraine-on-the-Lake

Highland Park, Illinois

27-29 January 1959

Quartermaster Food and Container Institute for the Armed Forces
Quartermaster Research and Engineering Command
Quartermaster Corps, U. S. Army
Chicago, Illinois

March 1959

QMF&CI Report No. 4-59

Proceedings

Contractors' Sixth Annual Meeting
Radiation Preservation of Foods Project
(7-84-01-002)

Presented herein is a summary of proceedings at the Sixth Annual Meeting of Contractors of the Radiation Preservation of Foods Project of the Quartermaster Corps at Highland Park, Illinois 27-29 January 1959. Appreciation is expressed to all those persons who served as roundtable discussion leaders and as secretaries for the technical sessions for their efforts in providing the summaries which have made prompt preparation of this report possible. Similarly, the expeditious submission of summaries of the speeches contained herein has facilitated the preparation of these proceedings by the Quartermaster Food and Container Institute for the Armed Forces.

Approval for release to qualified personnel participating in the program:

Harry E. Goresline

HARRY E. GORESLINE
Deputy Scientific Director, QMF&CI

Ervin L. Keener

ERVIN L. KEENER
Colonel QMC
Commandant

Quartermaster Food and Container Institute for the Armed Forces
Quartermaster Research and Engineering Command
U. S. Army
Chicago, Illinois

March 1959

I. INTRODUCTION

The Sixth Annual Contractors' Meeting of the Quartermaster Radiation Preservation of Foods Project was held 27-29 January at the Hotel Moraine-on-the-Lake, Highland Park, Illinois. Some 159 scientists and military leaders representing 38 industrial organizations, 28 academic institutions and 4 governmental agencies, participated in the program.

The convention was opened by Colonel Ervin L. Keener, Commandant of the Quartermaster Food and Container Institute for the Armed Forces. In his opening remarks, Colonel Keener mentioned that the expenditure of money and effort over the past five years in the Radiation Preservation of Foods Project has resulted in obtaining much needed basic knowledge as well as considerable progress in many areas towards achieving a food process of the future. Accordingly, it is essential to increase the effort devoted toward development of specific products, since the Project is being reoriented to the resolution of problems for development of meal-type feeding.

Major General C. G. Calloway, Commanding General of the Quartermaster Research and Engineering Command, Natick, Massachusetts, welcomed the participants on behalf of the Quartermaster Corps. Dr. Harry E. Goresline, Deputy Scientific Director of the Food and Container Institute, outlined the philosophy and mechanics of the meeting, emphasizing the change in format over the structure of previous meetings.

The first two days of the meeting were divided into a series of concurrent technical roundtables devoted to various aspects of the programs administered by the Office of The Surgeon General and The Quartermaster Corps.

The seminars presented on the third day by Dr. Herman F. Kraybill, U. S. Army Medical Research and Nutrition Laboratory, Denver, and Dr. Goresline, are reproduced in their entirety in this report.

Dr. Arnold Lehman, Chief, Division of Pharmacology, Food and Drug Administration, addressed the group at the annual banquet on the subject of, "The New Food Additive Law". Dr. Joseph Butts, Chairman, Department of Agricultural Chemistry, Oregon State College spoke at the annual luncheon, discussing, "The Program for Peaceful Uses of Atomic Energy in European Countries".

Summaries of these addresses are included in this report. Summaries of discussion at all the technical sessions likewise are presented.

THE NEW FOOD ADDITIVE LAW

Dr. Arnold Lehman

I am very happy to have this opportunity to meet with you this evening to discuss some matters of current interest involving the application of the Federal Food, Drug and Cosmetic Act. The Food Additives Amendment of 1958 is the newest, and in our view, most important change in the Act that has occurred since the basic pure food law was re-written in 1938.

The Food Additives Amendment seeks to make certain that substances which may reasonably be expected to become components of food or otherwise affect its characteristics are safe for their intended use. The language of the statute makes it clear that is is intended to cover indirect as well as direct additives, and specifically included any substances intended for use in packaging food.

Specifically, the 1938 law allowed chemicals to be added to food without any advance testing to establish their safety. The new law corrects this by requiring a food additive to be tested for safety, generally by industry, and accepted for proposed use by the Government before it may be shipped across State lines or used in food subject to the Federal law.

The new law permits the use of new additives at safe levels to advance food technology. It removes restrictions formerly present that blocked progress unnecessarily.

A substance becomes subject to the new law if it becomes a component of food or otherwise affects the characteristics of the food or may reasonably be expected to do so under the intended conditions of use. It is also subject to the law if it is not generally recognized among appropriately qualified experts as safe under the intended conditions of use; both old and new chemical food additives are covered if their use is not known to be safe. Additionally, food exposed to ionizing radiation is included in the amendment as a specific area which must be tested for safety before it is marketed.

This law is not going to change current practices materially for the more responsible elements of industry. These for years have voluntarily tested new substances before adding them to food, and have discussed their findings with us before marketing the additive or the food containing it. This, basically, is what the new law requires also.

Let us now consider some of the scientific aspects of the requirements of this new law in respect to the testing required to show that an additive is safe and suitable for food use. To summarize some of the more important points:

1. The additive must be identifiable, whether it is a single chemical or a mixture of chemicals. It is essential that the substance tested on animals for safety be the same substance and of the same degree of purity as the material to be employed commercially in food.

2. Analytical methods must be available to determine the concentration of the additive in the foods in which it is to be used, and frequently in animal tissues and fluids as well.

3. The safety of the additive must be determined by feeding it to test animals. The first of such tests is the acute oral toxicity test in laboratory animals such as rats, to determine what amount is required to kill them in a short time. This is followed by the subacute oral toxicity test during which feedings are continued for 90 days at each of several feeding levels. The effects of the chemical on food consumption, growth, mortality rate, blood and urine composition, weight, and microscopic structure of the organs are determined. The test for chronic oral toxicity is conducted on the premise that the possible effect of the lifetime consumption of a chemical in man's food cannot be predicted from results of tests less stringent than lifetime feeding in a short-lived animal, supplemented by one year or longer feeding in another species of test animal. Various biochemical and pathological procedures are carried out at autopsy to discover the fate of the substance in the body--whether it is excreted, unchanged or stored, or broken down into other chemicals.

Additionally, observations are made on such things as growth, food consumption, mortality, effect of the chemical on the blood stream, and on the behavior of the animal. The chronic toxicity test also gives information on any tendency of a chemical to induce cancer when consumed for a lifetime.

4. There must be data to permit the scientists to determine the probable intake level of the chemical. Under certain conditions the Secretary is required to limit the amount of additive which may be used to a level not higher than that reasonably required to produce the intended physical or technical effect, or to refuse to permit the additive at all if the evidence does not show it will produce the intended effect. In addition, our scientists must consider the possibility that the new substance may supplement or enhance the physiological action of the other chemicals already present in the diet. Therefore, they allow in man's diet considerably less than the maximum amount of chemical that

fails to cause injury to animals. Assuming that the average man is 10 times as sensitive to the additive as the test animal, and assuming that some men are 10 times as sensitive to the chemical as the average man, the combination of these safety factors allows in man's diet only 1/100 the quantity of a chemical that is safe in the animals diet. This is a guide only and may be varied as scientific data indicate to be proper.

It has indeed been a pleasure to meet with you and discuss the new food additives law of 1958.

THE PROGRAM FOR PEACEFUL USES OF ATOMIC ENERGY IN EUROPEAN COUNTRIES

Dr. Joseph S. Butts

In the United States before 1941 there was very little work done in the field of atomic energy. However, we all know of the tremendous growth in the program from 1941 to 1945 under the direction of the military. Then, in 1945, Congress passed the Atomic Energy Commission Act, creating a civilian agency. There are twelve divisions in the organization of the AEC, of which we are interested in two, the Division of Biology and Medicine and the Division of Research.

In the Division of Biology and Medicine several programs were developed, of which the medical program was first. The reactor program in the Reactor Division is the second big field of research. While the power program is being studied in this country, it is much more important to the British because they do not have natural resources and must turn to nuclear energy as a source of power. In the field of biology and agriculture, of which I feel most qualified to speak, I will list some of the areas of research which are not only supported by our Atomic Energy Commission, but were largely originated through this agency.

In the field of genetics I might mention hardiness of wheat, increased stem strength, increased yields, and other characteristics which can be bred into many plants, particularly the cereals. In addition, fertilizer placement studies have also proved successful and have made substantial savings. Although the phenomenom of photosynthesis has not been solved, great gaps in our knowledge have been filled.

Many of you are familiar with the screwworm fly story in the field of entomology. The fifth field to be considered is that of food preservation. I mention this field because it is being pursued actively on the continent.

In the 1955 Geneva Conference, the world became aware of what was being done in this field of atomic energy, as applied to biology and agriculture, medicine, and power. The various countries where little work was being done suddenly awakened to the tremendous possibilities in this program. The Office of European Economic Cooperation set up a program for biology and agriculture, in order to disseminate this information. Four American scientists were invited to come to Europe in order to implement the program. I was invited over for one year; the other three joined me after 6 months.

We were invited to each country where a program of visits was outlined. In the United Kingdom, work is being carried out at Harwell, comparable to one of our national laboratories; at Wantage, where the food irradiation experiments are being carried out; and at the Universities of Oxford and Cambridge.

The second country in which a program has been established is France. Work in plant breeding is being done in Versailles; the animal work is being carried out at Jouy-en-Josas. Twenty-two food companies have banded together under the name of "Conservatone", using the spent fuel rods from a reactor at Saclay for food irradiation. Saclay is one of the five French research centers possessing nuclear reactors. As soon as clearance is given from the Food and Drug Administration, it is planned to produce irradiated foods.

Norway and Holland collaborated in building a reactor at Kjellar. There is a small but excellent program at the Norwegian agricultural school at Vollebekk.

In Sweden, the Atomic Energy Program revolves around Professor Gustaffson, one of the greatest plant breeders in the world. He has used X-ray first, later, Cobalt-60 sources to bring about mutations in plants. The reactor here is built 20 meters into the rock in the heart of Stockholm.

The Danish program is just getting underway at the center at Risø. This will be a complete center for all kinds of isotope research. They also have a modern and up to date Meat Research Institute and expect to use ionizing radiation to sterilize food.

Holland is building the first reactor solely for agricultural and biological research at Wageningen. Programs are being carried out also at Groningen and Utrecht, but the center will ultimately be at Wageningen.

In Belgium, they have quite a complete atomic energy establishment at Mol, where they are actually producing some 40 or 50 different isotopes which are supplied to many workers in Belgium and nearby parts of Europe.

In Italy, a program is planned but has not been established. The center at Ispra will include a reactor and will be comparable to the Belgian establishment at Mol, the British arrangement at Harwell, and the French center at Saclay.

Germany can be characterized by saying it is a country which is building. The Germans were denied the use of isotopes and ionizing radiation until 1954, so while I saw blueprints of reactors and laboratories, there is as yet no country-wide program.

A reactor is under construction in Portugal, and in two or three places, some research is being done. Portugal is one of the countries whose research program will be well financed by the Gulbenkian Foundation.

In Austria, plans have been drawn for a program, but there is practically no work underway. There are some fine nuclear scientists in Iceland, but the foreign exchange is in such a bad condition that they cannot finance any program. There is currently no program in Ireland although I saw two places where isotopes were being used. Turkey and Greece are in much the same situation. Reactors are under construction, but in biology and agriculture I saw no research being done at all.

Spain is still in the training stage. Four or five young men are studying isotope research in America, and the biggest swimming pool reactor in the world is being built in Madrid but I do not know how much use will be made of this.

Yugoslavia is the only country I visited behind the Iron Curtain. I was amazed at some of the excellent biological work that was being carried out, but I did not see any work in the field of atomic energy.

In Switzerland agriculture is not a particularly important subject, and although some good basic work is being done, particularly in tracer techniques, very little work is being done in agriculture.

Certainly, the friendliness which was shown by the various scientists to me as an American was very great, and I feel the greatest dividends of my 12 months in Europe were the European friends that I made.

II. SUMMARY REPORTS ON TECHNICAL SESSIONS

In the section which follows, discussion at the technical sessions has been summarized for presentation.

MICROBIOLOGY

Chairman: Dr. L. L. Kempe

A number of participating contractors presented prepared summaries of their studies which had been made available to all participants by personnel of the Quartermaster Corps. These summaries appear as Appendix I to this report.

Following presentation of reports, the session was opened for questions. The subjects discussed are treated below under general headings. Where answers or comments were forthcoming from the assembled group, the answers are also presented in condensed form under the topic heading.

STERILIZATION REQUIREMENTS

A group of contractors suggested that consideration be given to a possible alternate criteria for establishing the radiation sterilization dose other than that which was used to set the current requirements of approximately 4.5 megarads. This proposed concept involved consideration of the natural microbiological flora at their naturally occurring concentrations in foods. The present dose level, approximately 4.5 megarads, is based on inoculated pack studies with large numbers of Clostridium botulinum spores. It should be stated that a member of the group suggesting this alternate approach based on natural flora pointed out that consideration based on this method would not necessarily result in a lowered dose requirement but could even lead to a higher one.

METHODS OF INTERPRETING SURVIVOR CURVE DATA

Two general approaches are used for interpreting survivor curve data to be used in determining the sterilization dose by the inoculated pack method. For lack of better definition these are called "end point" and D value determinations. The former involve inoculated packs with large numbers of spores per can, as well as, consideration of many cans as a single system. The D value approach utilizes slope of a survivor curve and a given number of log cycles to establish the dosage. Twelve cycles are suggested for this purpose but as many as 15 were discussed. It may or may not be significant that both methods currently arrive at about the same requirement for a sterilizing dose, viz., approximately 4.5 megarad.

Conditions influencing D value determinations were discussed. (1) Factors that indicate use of single strain spore suspensions rather than mixed strains were suggested. (2) A consideration of effect of spore concentration suggested that this might affect the D value calculation. (3) Somewhat different methods of D value calculation appeared to result in essentially similar values for the sterilization dose.

Both the end point and D value data were considered to be possibly affected by the following:

- the particular food under test
- spore recovery media and conditions
- spore growth media and conditions

It was proposed to use a uniform test food and uniform methods of D value determination. This change in procedure might lead to more uniform results but, perhaps uniformity is not the ultimate objective.

Comments on inoculated pack studies pointed out that inoculation of spore suspensions into the center of the can might possibly give different results than mixing spores throughout the food.

EFFECT OF STORAGE ON RECOVERY OF BACTERIA FROM FOOD

(1) No botulinius spoilage has been observed in inoculated cans beyond 3 months incubation. Recent data indicate that the incubation temperature which is best for germination is yet to be determined.

(2) More viable C. Botulinum spores have been recovered from frozen foods after a few weeks storage than could be obtained shortly after freezing.

More vegetative cells of bacteria remaining alive after irradiation have been recovered following about 3 months incubation than in the preceding interval.

POSSIBLE METHODS FOR LOWERING RADIATION STERILIZATION DOSE

(1) Develop 100% spore germination, then irradiate at pasteurization levels

(2) Inhibit germination of spores

(3) Combined processes; heat, antibiotics, potentiating chemicals etc. with irradiation

(4) Intermittent irradiation - Preliminary studies indicate there is some possibility of this method being successful

(5) Different dose rates

(6) Different temperatures - perhaps high enough to utilize known combined irradiation - heat phenomen

It was suggested that since the Quartermaster Corps schedule calls for four radiation processed foods to be available by 1963, plans would best be made on what we know now rather than relying on future data.

The suggestion was offered that a critical compilation and evaluation of work to date on the various aspects of the preservation of food by irradiation would be useful. Such a study would include original work as well as present conclusions and should draw on the manifold sources of industry, the universities and the Quartermaster Corps.

APPENDIX

Research Center
American Can Company
Barrington, Illinois

Official Investigators:
E. Wheaton, G. B. Pratt &
A. C. Wilbur

Title of Contract: Comparative Radioresistance of Selected Strains of *Clostridium botulinum* in Selected Food Products.

1. Objective: The objective of this project is twofold - namely, to indicate the effect of different types of food products on the radioresistance of the selected strains of Cl. botulinum, and the effect of food products on the relative resistance among selected strains of Cl. botulinum.

2. Results: The radioresistance of a given strain may be contingent on the type of food, as preliminary findings indicate a significantly greater kill in green beans than in animal products. The highest recovery of spores was found in the chicken and codfish. Initial counts on the uninoculated products (green beans, beef, chicken, codfish, and pork) were of a low order, but high enough to allow some spoilage after an irradiation dose of 1.7 Mrads in beef and pork, and practically 100% spoilage due to the natural microbial flora in all five products after a dose of .85 Mrads.

3. Food Radiation Application: The information to be obtained should indicate whether dose levels required for food sterilization have to be determined for each type of food product to be so preserved.

Continental Can Company, Inc.
Chicago 20, Illinois

Official Investigator:
Dr. Clarence Schmidt

Title: Comparative Resistance of Strains of Clostridium Botulinum to Ionizing Radiation

SUMMARY

The purpose of this work is to determine the gamma radiation resistance of spores of single representative strains of Cl. botulinum including types A, B, C, and E, in a common irradiation and recovery substrate. The substrate being used is a beef stew formulation including cooked meat, blanched potatoes, blanched peas and gravy. Resistance is determined in terms of a radiation D value calculated from partial spoilage results at one or more irradiation levels. Partial spoilage results are obtained by inoculating 100,000,000 spores per can into 202 X 202 cans and irradiating 20 can lots at selected dose levels between 2.0 and 3.0 megarad.

Experimental data obtained to December 1, 1958, have given the following results:

Strain	Type	Tentative Radiation D Value (megarad)
62	A	0.29
109	A	0.32
T	A	0.29
169	B	0.29
12033	B	0.29

If the above tentative radiation D values are not significantly altered by further work, it would appear that the maximum range of variation of D values for these five strains in this substrate is about 10%. Completion of the work intended under the scope of this project will demonstrate the maximum range of resistance of at least 24 different strains.

52249 O—60—pt. 1——18

Continental Can Company, Inc.
Chicago 20, Illinois

Investigator:
Dr. Heinen

Title: Radiation Sterilization of Canned Foods

SUMMARY

The purpose of the work currently in progress under this project is to determine the effect of meat curing salts on irradiation survival, germination and outgrowth of spores of Cl. botulinum. Six different formulations of ground ham, corresponding to six different cure compositions were inoculated with spores of Cl. botulinum, mildly heated, and subjected to gamma irradiation followed by incubation. Radiation levels of 0.465 and 0.93 megarad did not prevent spoilage and the development of toxicity in any formulation. No toxic swells were encountered following irradiation at 2.79 and 3.72 megarad, although two formulations each gave one swelled non-toxic sample at 3.72 megarad. Irradiation at 1.86 megarad resulted in toxic spoilage in one formulation and one sample of non-toxic spoilage in another formulation.

Since these results are based on only 10 can lots for each formulation - irradiation variable, it might be expected that larger sample lots or a higher level of spore inoculum would result in spoilage of other formulations at the 1.86 megarad radiation dose or even at the 2.79 level. These results do not appear very favorable to the hope that the presence of meat curing salts might permit the radiation sterilization of ham at a dose level not causing undesirable organoleptic effects.

Michigan State University
East Lansing, Michigan

Official Investigators:
Dr. Ralph N. Costilow
et al

Title of Contract: Investigation of Physiological Factors Which Contribute to the Radioresistance of Spores of Clostridium botulinum.

SUMMARY

The objective of this study is to elucidate factors which affect the radioresistance of Clostridium botulinum spores. The work thus far has been directed toward the development of techniques and procedures for use, and testing of the effect of a few factors on the apparent radioresistance of spores.

The most interesting observations made so far are (1) spore suspensions of Cl. botulinum 62-A have a greater apparent resistance when irradiated in polyethylene bags than when irradiated in open petri dishes, (2) heat shock applied prior to irradiation at $1x10^6$ reps results in a greater number of survivors than when applied after irradiation, but this is not true when an irradiation level of $7.5x10^5$ reps is used, (3) there is no significant difference in the radioresistance of spores suspended in distilled water and in phosphate buffer concentrations ranging from 0.067 to 1.0M at pH 7.0, and (4) small aluminum cups for use in a thermoresistometer appear to be excellent containers for irradiating multiple samples with a cathode ray for end-point destruction determinations.

This type of work is a prerequisite to our study of factors influencing the radioresistance of Cl. botulinum spores. This, in turn, is necessary in order to ascertain the maximum resistance which such spores may have and what treatment, if any, can be used to reduce this resistance.

Contractor: National Canners Association, Washington, D. C. with the Research Laboratories of American Can Company, Continental Can Company, and N.C.A. Western Laboratory

Official Investigators: Dr. Greenleaf et al

Title: Study of the Destruction of Food Poisoning Organisms in Canned Food Subjected to Ionizing Radiation.

Objective: To determine the absolute or practical lethality of gamma radiation with respect to Clostridium botulinum in canned foods.

Summary: Five different foods inoculated with 10 strains (5 type A and 5 Type B) of Clostridium botulinum spores (about 1 million composite spores per can) have been irradiated at 5 or 6 different dosage levels using 100 cans at each level of irradiation. Cans have been incubated and also (6) subcultured immediately subsequent to irradiation.

Results to date:

	Results in mega-rad	
Frozen temperature irradiation	Spoilage*	No. Spoilage **
Cream of Chicken Soup	3.255	3.348
Blanched Peas	2.418	2.79
Par-boiled Ground Pork	3.255	3.441
Room temperature irradiation		
Cream of Chicken Soup	2.604	2.79
Blanched Whole Kernel Corn	2.883	3.255
Par-boiled Ground Beef	2.604	2.79

* Toxin confirmed by mouse injection.

** No spoilage which produced toxin; (non-toxic spoilage has been found in chicken soup and pork at the higher levels).

Evaluation: In the absence of additional practical experience, it appears that the only method at hand for determining a safe radiation sterilizing dose is to extrapolate the results on these can numbers and spore concentrations to those which might be encountered in commercial production. We feel that public health safety is the first step in developing a new method of food preservation.

National Canners Association
Western Research Laboratory
Berkeley, California

Official Investigators:
Charles Townsend et al

Title: Determination of Relative Resistance of Selected Strains of Clostridium Botulinum to Ionizing Radiations

SPECIAL SUMMARY FOR ANNUAL CONTRACTORS MEETING 1959

Spores of nine strains of Cl. botulinum type A, seven type B and six type E are being individually irradiated at room temperature in each of three substrates: beef broth, M/15 phosphate buffer, and pork-pea broth. One type C strain will be included if a satisfactory spore suspension can be obtained. The objective of this study will be to demonstrate which of the selected strains possesses the greatest radiation resistance.

Sealed glass thermal death time tubes containing 2.5 ml of liquid with an inoculum of one million spores per milliliter are being used. In order to obtain a well-defined resistance curve an effort is made to select three exposure levels which will result in the survival of approximately 100,000 (90% destruction), 1000 (99.9% destruction), and between one and 10 spores per ml (99.999% + destruction).

Duplicate tubes of each strain are simultaneously irradiated at appropriate levels by means of a Linear Electron Accelerator. These exposures are repeated three times at intervals of several weeks.

To minimize spore germination, inoculum and substrate are refrigerated before and after they are combined. Between manipulations the sealed tubes are held at approximately 33°F. Inoculation, exposure and subculturing are carried out in as rapid a sequence as possible. The effect of holding the irradiated tubes overnight at 33°F. instead of subculturing them immediately after irradiation is currently being investigated.

Exposures in beef broth are in progress and a limited amount of data have been compiled which indicate that type A strains are generally the most radiation resistant and type E strains the least. There appears to be some overlapping, however.

When the percentage survivors are plotted on a logarithmic scale versus the dosage on a linear scale, a curve drawn through all the points and the origin is more sigmoid than linear in shape.

The most resistant of these strains will be irradiated at a larger number of sublethal levels. The resultant radiation destruction curve will be somewhat analagous to the classical thermal destruction curve of Esty and Meyer. This strain will then be used for extensive inoculated pack studies (under other contracts) for the purpose of determining commercial sterilization dosage requirements.

Oregon State College
Corvallis, Oregon

Official Investigators:
Anderson et al

SPECIAL SUMMARY FOR ANNUAL CONTRACTORS MEETING

The main objectives were to determine the gamma radiation resistance of radiation resistant microorganisms in the presence of salts, spices, different temperatures, various kinds of meats, changes in hydrogen ion concentration, various gases, and different classes of antibiotics.

Difficulties have been encountered in using radiation as the only means of sterilization because of the high dosages required. Investigations of the above factors could lead to the use of lower radiation levels resulting in less of the objectionable side effects.

Radiation intensities up to 4.65 megarad were found to be more effective in obtaining sterility than the lower previously recommended level of 2.79 megarad. Facultative anaerobes were recovered from several samples irradiated to 2.79 and 4.65 megarad. Indications were that these are species which survived the radiation treatment.

A simplified technique permitting the pipetting of raw pureed meats for quantitative bacteriological study was developed for use in determining survival curves of nonsporing bacteria resistant to radiation.

Survival curves of the radiation resistant bacterial strain in various menstrua including the pureed meats showed that resistance was significantly greater in raw beef and chicken than in raw fish and in cooked beef. Its resistance was lowest in buffer. Cells grown in broth (an artificial growth medium) and resuspended in beef did not differ in resistance from cells that had been grown in the beef and then irradiated.

Survival curves using gamma radiation as the sterilizing agent were determined in raw beef using four strains of Micrococcus radiodurans and one culture of Bacterium radiodurans. B. radiodurans, a gram positive rod, was as resistant as R_1, the most resistant strain of M. radiodurans.

The addition of an antibiotic followed by irradiation is more effective than either one used separately, and appeared to increase markedly the killing action of gamma radiation at levels of 0.1 megarad.

The gamma-resistant micrococcus was shown to be more resistant to ultraviolet light (UVL) than other nonsporing bacteria or spores of Bacterium subtillis morphotype globigii. No great differences were detected in rate of kill when the radiation resistant micrococcus was irradiated with gamma rays at different pH levels in phosphate buffer or at different temperatures ranging from 32° to 130°F. No differences in inactivation rates were observed in the presence of oxygen, nitrogen or sublethal concentrations of H_2O_2.

Vacuum sealed inoculated meat packs were irradiated in the presence of different spices and varying concentrations of NaCl. Results show that radiation in the presence of cinnamon and mustard oil reduced the surviving bacterial numbers greater than could be attributed to either radiation or the spice alone. Salt up to 3% had no apparent effect, while all the other spices used appeared to protect the organisms from radiation death. The protective effect of garlic was most pronounced, resulting in a ten-fold recovery over the control.

University of Michigan
Ann Arbor, Michigan

Official Investigator:
Dr. Lloyd L. Kempe et al

Title: Determination of Radiation Sterilization Dose for Canned Meat

Previous studies have indicated a semilogarithmic relationship between spore concentration and the radiation sterilization dosage of gamma radiation for cooked ground beef packed in tins. The previous data included Cl. botulinum and PA 3679 spore concentrations up to 4×10^4 per gram. Our present work has extended these data to include both cooked and raw ground beef inoculated with more than 10^6 spores per gram.

RESULTS

Cooked Ground Beef

Cl. botulinum 213B spores
0.34 megarad = D value
3.8 megarad = sterilization dose using 5×10^6 spores per gram of meat

Cl. botulinum 62A spores
3.85 megarad = sterilization dose using 5×10^6 spores per gram of meat

Raw Ground Beef

Cl. botulinum 213B spores
3.72 megarad = sterilization dose using 1.7×10^6 spores per gram of meat

Cl. botulinum 62A spores
Sterilization dose still not established at 10^6 spores per gram but data indicate about the same values as obtained for cooked ground beef.

Inoculated cans of ground beef that had previously been sterilized by gamma radiation have been stored in our laboratory for several years. Some of these cans were prepared as long ago as 1953. It is to learn whether spores that were "killed" by ionizing radiations could have germinated and evolved through a few divisions and thus developed enough toxin to be discoverable. Also, there is the possibility that spores of Cl. botulinum could remain alive but ungerminated in the meat and that these spores could be revived by subcultu

So far none of the cans of meat taken at or above irradiation sterilization levels for the particular experimental group under test have yielded botulinum toxin that would kill mice upon intraperitoneal injection. Occasiona a few gram positive rods are found in the meat. Their significance has not yet been established.

Contractor: Quartermaster Food & Container Institute For the Armed Forces
Food Division
Chemistry & Microbiology Branch
Microbiology Laboratory

Investigator: Abe Anellis

Collaborators: D. A. Huber
Helen Zaborowski

Title: Determination of the differences in resistance of Clostridium botulinum types and strains to ionizing radiation.

Objective: To determine differences in radiation resistance between and within types of Cl. botulinum spores.

Summary: 7 strains of Type A and 8 strains of Type B spores of Cl. botulinum were screened for resistance to gamma rays. About 10,000 spores per tube were suspended in phosphate buffer pH 7.0 and irradiated under nitrogen. Among the Type A strains, the range of lethality varied between 1.0 to 1.4 megarad with 4 of the 7 strains requiring 1.4 megarad for their complete destruction. Among the Type B strains, the degree of sensitivity covered a broader lethal dose range - 0.6 to 1.4 megarad; 4 of the 8 strains were destroyed by less than 1.0 megarad, and the other 4 strains required 1.0 to 1.4 megarad for total inactivation. The difference in radioresistance between the least sensitive and the most sensitive of the 15 organisms tested are represented by strain 62A (D_D = 223.6 and D_S = 1200 kilorad) and strain 51B (D_D = 128.3 and D_S = 600 kilorad).

Evaluation of Work: Since definite variations in radiation sensitivity were observed among strains of Cl. botulinum, it is of importance to find and use the most resistant strain in determining adequate dose requirements for the safe preservation of irradiated foods.

H. J. Heinz Company
Pittsburg, Pennsylvania

Official Investigator:
Dr. I. J. Hutchings et al

Title: The Effect of Various Levels of Irradiation Dosage Upon the Heat Resistance of Food Spoilage Organisms (strains of Clostridium botulinum)

CONTRACT RESEARCH PROJECT SUMMARY

The objective of this work is to study the effect of various levels of irradiation dosage upon the heat resistance of food spoilage organisms (strains of Clostridium botulinum).

Various types of food have been inoculated with Clostridium botulinum spores and exposed to various levels of irradiation dosage. Exposure to irradiation occurred in the frozen state and subsequent to irradiation, the rate of reduction curves of the residual spores were determined using thermo-resistometer technique. Two soups were used in this work, Split Pea Soup, representing the high protein type of soup, and Cream of Chicken Soup, a lower protein soup.

In Split Pea Soup, which was exposed at levels from 502,200 to 2,008,800 rads, it was found that the rate of reduction in spore resistance of the spores of Clostridium botulinum when plotted on semilog paper with D values on the log scale and the dosage in rads on the linear scale a straight line, exponential reduction in resistance curve was obtained. The same held true for spores of Clostridium botulinum in condensed Cream of Chicken Soup exposed at the same levels. In general, the D_{240} value of the spores in the Split Pea Soup, which had the higher protein content, was greater than the D_{240} value in the lower protein content Chicken Soup.

Before a critical irradiation program can be developed, it is necessary to have a fundamental knowledge of the effect of irradiation on spore resistance in order to develop a program which will utilize irradiation treatment of foods.

Dr. Louis Beraha

Discussed studies of lethality of ionizing radiations for fungi other than bacteria.

0.5 to 1.0 megarad needed to inactivate ionidial spores of molds while vegetative cells are killed by 0.1 to 0.3 megarad.

Discussed methods by which the studies were conducted.

Dr. Alex Malaspina

Discussed his paper with R. F. Cain and A. W. Anderson entitled, "Effect of Radiation on Antibiotic Treated Meats". Food Tech. XII (11) 582-584 (1958)

Dr. Walter Clark

Discussed possible use of antibiotics in combination with ionizing radiations for food preservation.

THE CHEMISTRY OF SENSORY CHANGES

Chairman: Dr. W. Dexter Bellamy

Considerable progress has been made since the last meeting in methods for fractionating irradiated meat, but there is no general agreement on which of the many isolated products, compounds, and types of compounds are chiefly responsible for odor. It seems reasonable, however, to concentrate more effort in the next year upon irradiated cooked meat since these will be used first in products produced by the Quartermaster Corps. The following is a summary of the comment presented during this session.

Word descriptions of several odors seem to be generally accepted. The irradiated raw meat odor was described as "wet dog", and a 50% solution of irradiated egg albumin gave a similar odor. Dr. Merritt of Natick, however, described the same odor as a "sewer odor". Dr. Emory of General Mills reported a nauseating odor and flavor in flour which had been irradiated aerobically or anaerobically; the nauseating odor and flavor was observed at relatively low doses from 93,000 rads and up. He also reported that irradiated sugars exhibited a burnt odor and when incorporated into flour induced the same nauseating odor as irradiated flour.

Dr. Betty Watts found a stale odor in stored cooked pork, which developed in both irradiated and control samples. Its presence was prevented by the addition of antioxidant. Dr. Bellamy reported a "wet chicken" feather odor in the methanol extract of irradiated egg albumin which appeared to be due chiefly to amines. The odor of other products or fractions was not described in general terms.

The compounds identified in irradiated beef by Dr. Merritt of Natick were acetaldehyde, acetone, methylethyl ketone, isobutyl mercaptan, dimethyl disulfide, methanol, ethanol, hydrogen sulfide, methyl mercaptan and ethyl mercaptan. Dr. Burks of the Southern Research Institute found ammonia, methyl amine, ethyl amine and 4 unidentified amines in the distillate from irradiated beef which had been made alkaline. Dr. Bellamy reported acetic acid, formic acid, properic acid and butyric acid as well as acrolein and pyruvic acid in the acid distillate of irradiated egg albumin.

Several fractionation procedures were described. The details of these procedures can be found in the individual reports, but the brief descriptions given below will illustrate the variety of methods used and the difficulty of comparing fractions.

Mr. O. F. Batzer of the American Meat Institute Foundation extracted fresh and cooked beef, and fractionated the water extract with ammonium sulfate. All fractions were irradiated and all the fractions were analyzed for carbonyls, mercaptans, hydrogen sulfide and presence of sulfhydryl groups. In fresh meat, the bulk of hydrogen sulfide and methyl mercaptan was found in the fractions precipitated by 60 and 70% ammonium sulfate; these fractions would include proteins of the myogen group of enzymes. In cooked meat, the only fraction which yielded appreciable amounts of hydrogen sulfide and methyl mercaptan was the original water-extract dialysate.

Dr. Paul Hedin of CMF&CI extracted cooked beef with 10% NaCl. The extract was dialyzed and both the dialysate and residue were irradiated. Carbonyls were present in the dialysate, but the odor was not offensive. The irradiated residue had a definite "wet dog" odor. Of particular interest was the observation that dialysis removed the irradiation odor components, and that a second irradiation of the dialyzed irradiated residue produced very little additional odor. This indicates that this part of the irradiation odor appears to have a finite origin.

Dr. S. A. Goldblith of MIT briefly described results obtained with an apparatus for concurrent radiation and distillation. Both milk and ground beef were studied. Principal problems encounted with milk were gelation and browning rather than off-odors. Some of the volatile compounds from concurrent radiation distillation of ground beef were isolated in several classes, (i. e. carbonyls compounds, amines and sulfur compounds). Characterization of these classes is proceeding, and cooked beef will be studied next.

Dr. Bellamy of General Electric lyophylized irradiated solutions of egg albumin, and serially trapped fractions at -90°C and -197°C. The -90° had a musty earthy odor while the -197° had an offensive "putrid" (mercaptan) odor. The residue had a strong offensive odor like "wet chicken feathers", and could be extracted with methanol. The material in the extract gave many of the reactions of amines, but not of mercaptans.

Dr. Charles Merritt of the Pioneering Research Division described in some detail his vacuum distillation procedure for trapping volatiles from irradiated raw beef and their examination by mass spectrometry and gas chromatography. He reported that their group felt that the major part of the "irradiation odor" appeared (by their method of fractionation) in the water-soluble fraction rather than in the none volatile fractions they had been able to identify. Characterization of components in the water-soluble fraction is proceeding, but is very difficult because of the presence of the water.

Possible methods for control or prevention of these odors were discussed. These might be listed as follows:

1. A reduction in the original number of bacterial contaminates should result in a lower sterilization dose and therefore, result in less off-odor and flavor. This approach of course, is being worked out in the microbiological part of the project.

2. The exclusion of oxygen results in less irradiation odor, but there was no universal agreement that all odors were better in the anaerobic and aerobic irradiated material.

3. The addition of free radical acceptors such as ascorbic acid and sodium nitrite. Dr. Ezman of the University of Michigan reported that a tomato paste or a mixture of dextrose, alpha tocopherol and beta carotene added to ground beef before a combined irradiation and heat treatment effectively prevented the immediate development of the "wet dog" odor. It was noted that added tomato paste (being acid) should cause increased volatility of acidic components (like H_2S) but should make basic components (like amines) less volatile. It was generally agreed that the free radical acceptors are only partially effective.

4. The masking of functional groups such as thiols and thials formed by sulfhydryls and carbonyls was suggested. Dr. Bellamy reported that the addition of pyruvate to egg albumin will prevent the "wet dog" odor, but will replace it by a burnt odor. Dr. Cain of Oregon State reported that flushing with N_2 or Co_2 during irradiation of cooked beef had greatly reduced the "wet dog" odor.

A discussion of the reason for less odor production in irradiated cooked meat were inconclusive, but it may be that heating has removed or masked many of the functional groups that contribute to the "wet dog" odor.

It was evident from the work reported that greater progress could be made if the individual investigators would check each other's results where an overlap of material or procedure occurs. It was agreed that such cross-checking would be accomplished in the year ahead.

PACKAGING

Chairman: Dr. G. G. Rumberger

RIGID CONTAINERS

Various investigators reported the progress of their work on metal containers. Tin plate and commercial steel were found to be satisfactory for use in sterilization operations by radiation. Some difficulties have been encountered with enamels, especially in the presence of high acid foods. In some cases, enamels meant for thermal processing are satisfactory for radiation sterilization, but this can not be considered a fixed rule. In regard to certain specific enamels, better results have been obtained with radiation than with heat, and in other enamels the reverse is true. Enamels are currently available which should satisfy the requirement for each specific food item with either means of treatment.

In respect to aluminum cans, the enamel systems have not yet been established, but work on this problem is in the initial stage. It appears that enamels for tin plate may not necessarily work for aluminum. High purity aluminum and aluminum alloys were compared in relation to can corrosion. This problem may merit further attention.

Can sealing compounds have proven generally satisfactory, with the exception of those containing butyl rubber. In the case of butyl rubber, softening occurs due to depolymerization, while with other can sealing formulations there is an increase in strength due to cross-linking.

Induced radioactivity was discussed. However, this subject is treated in the report on Nuclear Effects, and will not be detailed here.

Several problems still exist in spite of the generally good performance of tin plate cans. Where items containing carbohydrates and water are irradiated with sterilizing doses there is substantial evolution of hydrogen. This requires very close control of fill, vacuum, and closing techniques. Further study of factors bearing on this problem include study of food modification, control of head space and degree of vacuum. This problem is considered of high importance, as either excessive head space or extremely high vacuums may impose severe strains on both tin plate and aluminum cans, in addition to requiring very close control.

Although enamels can be chosen which are functional, we still lack information in respect to substances released by radiation which may be extracted by the foods. This problem is currently under investigation. We need similar information on sealing compounds, and plans are being made to obtain this when a satisfactory experimental design can be devised.

In respect to metal cans, all the data available concerns either heat or radiation treatment alone. If it becomes necessary to resort to combined heat and radiation, or radiation in conjunction with any other thermal energy sources, it may be necessary to consider metal cans in light of the new process.

FLEXIBLE PACKAGES

Various contractors reported on progress of work on plastic packages. A broad spectrum of films have been tested for durability after radiation. Most films do not suffer from degradation of tensile properties with the exception of those containing halogens, such as poly-vinyl chloride, Flurothene and Kel-F. One high density polyethylene lost some tensile strength and seal strength. From the standpoint of functional value in packaged foods, all films which will ordinarily be satisfactory for a given unirradiated food, will also be satisfactory after radiation, except as noted above.

With polyethylene and other films there is a problem of stress cracking. Polyethylene has been studied in some detail in this regard. In the unirradiated state, high density polyethylene is more resistant to stress cracking than the low density product, but after radiation the reverse relationship exists, with resistance of both increased. Stress cracking is aggravated by contact with low surface tension liquids such as fats and oils, and aqueous solutions of surfactants, such as lactic acid. Other factors, such as method of film manufacture, nature of food ingredients in contact with the film and temperature may be important. This work is continuing.

All of the films used for resistance to radiation have shown a large increase in water extractable materials after exposure to sterilization doses in contact with the test water. Even polyethylene (commercial) gave increased quantities of extractable material. These extractables have not as yet been identified, and it appears that an intensive study of the nature and amount developed from the most promising films is imperative.

It was pointed out that oriented polystyrene gives low odor and taste after irradiation, and might be a promising candidate for further investigation. There are several disadvantages to this material at present, including low resistance to fats and oils, difficulty in heat sealing, and high gas and water vapor transmission. These properties may be modified by combination with other materials, modification of the base polymer, or surface treatment with coatings.

Currently, the most serious problem with plastic packages has been the high percentage of extractable material after irradiation. It is imperative that a detailed study of the amount and nature of these potential contaminants be undertaken, as they may constitute a potential toxicity hazard.

It should be pointed out that after the close of the meeting reported above, the Microbiological Session considered the possibility of combining heat and radiation as a means of producing acceptable sterile packages. If this concept materializes it may require a complete reconsideration of the packaging program with both rigid and flexible containers.

CURRENT STATUS OF PROGRAM ON CARCINOGENICITY AND HISTOPATHOLOGY

Chairman: Dr. L. J. Teply

Lt. Col. Bernard Skold, Armed Forces Institute of Pathology, discussed the collection and correlation of histopathological data from contractors performing animal tests on radiated foods. The bulk of these data are yet to be submitted. Dr. Rigdon, University of Texas Medical Branch, presented a series of slides showing histopathology in rat tissues obtained from experiments on radiated foods conducted in Dr. Richardson's laboratory, Texas A & M College. These slides illustrated various tissue abnormalities that contractors studying wholesomeness of radiated foods might encounter. In some cases the terminology to be applied is not clear. Lt. Col. Skold suggested that each pathologist "call them as he sees them." The slides can be subjected to further study at the Armed Forces Institute of Pathology.

In summary, Dr. Rigdon's report was as follows: "There are three basic pathologic processes observed in our study of rats fed irradiated beans and chicken. As far as we can determine at this time none of these are related to irradiation per se but are associated only with the food these animals are receiving. A few neoplasms have occurred in the breast, subcutaneous tissues, kidney and urinary bladder. Calculi are present in the kidney, urster and urinary bladder. These stones are composed of blue staining material consistent with calcium. In the kidneys, calcium may be demonstrated in the renal tubules and in the stroma about the renal pelvis. Hydronephrosis and occasionally infection are associated with the renal obstruction.

A third lesion, found in a large number of animals, occurs in the pancreas. In the focal area of the pancreas, vacuoles are present in the epithelial cells lining the pancreatic acini. In the hematoxylin and eosin stains there are small, clear spaces within the cytoplasm. These are similar to the lesions observed in the pancreas of ducks fed a diet containing a high content of sucrose. (Proc. Soc. Exp. Biol. and Med. 80:165, 1952)

A few of the rats have shown a non-specific infection in the genitourinary tract, a few have shown chronic endocarditis and myocarditis. Essentially every animal has had an acute and chronic pulmonary infection. An acute gastric ulcer has been observed in several animals.

The remainder of the session was devoted to reports on studies on possible carcinogenicity of radiated foods. Mr. Kline, Wisconsin Alumni Research Foundation, reported on the completion of two year rat studies involving the feeding of four different control and radiated food product mixtures and injection of control and radiated lard. There was no difference in tumor incidence between groups fed or injected with control and radiated foods.

52249 O—60—pt. 1——19

Twenty-two separate feeding, skin-painting, and injection experiments on several different strains of mice have been completed except for final histopathological studies. The experiments were initiated in November 1954, and each experiment was of 13 to 24 months' duration. The results show no significant difference in tumor incidence between groups exposed to control and radiated products.

Dr. Read of the U. S. Army Medical Research & Nutrition Laboratory reported that the long term rat feeding tests carried out at his laboratory have given no indication of the production of carcinogens resulting from the irradiation of foods.

Dr. Huseby discussed the philosophy of approach in the development of the program of carcinogenicity studies in mice. Projects have been initiated in several additional laboratories involving the use of various mouse strains, each of which shows considerable spontaneous incidence of a particular tumor, mammary tumor or leukemia, for example. It has been shown that the extent of incidence and the rate of onset of these tumors can be affected by various factors. The projects are not far enough along to permit conclusions as to tumor incidence but reports were given on the progress of the experiments.

Dr. Kay, Industrial Bio-Test Laboratories, and Dr. Radomski, University of Miami, reported on the feeding of diets made up completely of radiated food items to three different strains of mice. Considerable difficulty has been experienced in obtaining satisfactory survival of the mice. It was pointed out that this is a general problem at present as far as commercially produced mice are concerned. Salmonella infection appears to be a major factor. The situation is improving and better performance has been observed in experiments started recently.

Dr. McKee, UCLA, has fed control and radiated bacon fat mixed with laboratory chow to two different strains of mice for 14 months. So far there is no difference in incidence of tumors between the groups on control and radiated fats.

Dr. Monsen, University of Illinois, College of Medicine, is feeding two strains of mice bred in his own laboratory a mixed radiated diet and has had good survival over a one year period. A number of mice of the Cb strain on the radiated diet have died with a heart condition characterized by dilation or rupture of the left auricle. Experiments have been started to find out if differences in vitamin levels are a factor. So far no differences in tumor incidence have been observed between control and radiated groups.

The general conclusion that can be drawn from all of the carcinogenicity experiments to date is that there is no indication of the production of carcinogens due to the irradiation of various foods over a wide range of dosages.

CURRENT STATUS OF LONG TERM RAT FEEDING EXPERIMENTS ON IRRADIATED FOOD

Chairman: Dr. L. R. Richardson

A total of 20 foods has been fed to rats for periods ranging from 38 to 104 weeks in a long term feeding study to determine the nutritive properties of irradiated foods. The food received doses of zero, X and 2X rads of gamma radiation. In most cases, the X dose was 2.79 megarad and 2X dose was 5.58 megarad. The irradiated foods were stored for a minimum of three months at 70 to 75°F, and most foods were cooked immediately before being mixed in the diet. The diets were mixed twice weekly in most laboratories and adequate amounts of both water and fat soluble vitamins were supplied in practically every test so that this study measured the adequacy of irradiated foods rather than the vitamins which they supplied.

The experimental design was that recommended by the University of Chicago Statistical Research Group and concurred in by the Food and Drug Administration for testing single foods or for testing two foods simultaneously. Essentially every food was tested by incorporating at a level of 35% solids in a diet that was nutritionally adequate for the rat.

The foods tested simultaneously at the various laboratories using the rat as the experimental animal are as follows; codfish and sweet potatoes were tested at Alabama Polytechnique Institute; corn and tuna at Hazelton Laboratories; evaporated milk and beef stew at the University of Miami; the Texas Agricultural Experiment Station tested tested chicken and green beans; and bacon and fruit compote were tested at the University of California at Los Angeles. Pork, peaches, jam, and carrots were each tested separately at Oregon State College; and beef was tested separately at Vanderbilt University. Studies were conducted on chicken stew and cabbage in one test, and shrimp and peeled oranges in the second test, at the University of Syracuse Biological and Food Research Center; unpelled oranges, also, were tested separately at this institution. (cabbage received 0.279 and 0.558 megarad and oranges received 0.139 and 0.279 megarad of gamma radiations). Potatoes which had received doses of zero, 15,000 to 22,000 rep and 30,000 to 44,000 rep were tested at the University of Michigan; and potatoes which had received zero, 7,500 to 8,500 and 15,000 to 19,000 rads were tested at the Wisconsin Alumini Research Foundation.

All values used to measure the effect of irradiation such as rate of growth, reproduction, and lactation, fertility (number of pups born, weaned, and weaning weight of pups) and longevity and hematological values, such as hemoglobin, microhematocrit, total and differential white cell count, tumors, and abnormalities did not differ significantly in rats receiving irradiated foods from those receiving the control foods.

The Army Medical Research and Nutrition Laboratory fed a diet which approximated the Military "A" ration, and the foods had received 0, X and 2X rads of gamma radiation. All foods (except potatoes) were stored 3 to 6 months at room temperature prior to incorporation in the diet. No vitamins were added to the diet. There was a decreased rate of growth proportional to the radiation dose. This slow rate of growth was partially overcome by the addition of pyridoxine, but the data indicated that some other nutrient was either lacking or supplied at a suboptimun level.

Summary:

In summary these tests show that, when the diet is supplemented with adequate amounts of both the water and fat soluble vitamins, the nutritive value of irradiated foods is equal to that of nonirradiated foods for the life cycle and longevity of rats.

PLANT PRODUCTS

Chairman: Dr. Louis Beraha

Several products were irradiated at the Quartermaster Food and Container Institute for the Surgeon General's long term feeding program and were held for wholesomeness evaluation. Among these, sliced cabbage pasteurization-irradiated at 300,000 rads and held under refrigeration for 35-40 days was very acceptable and edible with only minor changes in color and texture. Carrots blanched for one minute at 210 F. and sterilization- irradiated at 4.8 megarads resulted in softening of tissue. However, the addition of calcium chloride improved the texture, and the product in general was acceptable. Nearly the same results were obtained with sweet potatoes given a minimum blanch. Omission of a blanch resulted in browning of peaches irradiated at 4.8 megarads, while with a blanch, the texture was poor, and was followed by carmelization on storage. This type of undesirable change is also observed in heat processing.

Since a sterilizing irradiation dose impairs acceptability and does not inactivate deteriorating enzymes in the ranges generally used for processed food, attempts were made at the California Packing Company to combine heat treatments shorter than the recommended levels and irradiation at doses less than necessary for complete sterilization if these processes were used separately. These combination processes were effective in sterilizing canned peas and green beans inoculated with heat resistent spores. However, the combination processed peas were only partially acceptable, while green beans were unacceptable even at the lowest dose tested -- primarily because of texture. The non-irradiated heat processed peas and green beans were rated superior in every respect to those combination processed.

Factors affecting results obtained in the irradiation of fresh fruits and vegetables for their preservation have been dose and dose rate, temperature prior to and after irradiation, variety and maturity of the commodity, packaging, and gas exchange during irradiation. These factors are being studied at Utah State University. In general, doses up to 200,000 rads have increased the shelf life of certain fruits and vegetables for 2-4 weeks without deleterious effects. A pre-irradiation treatment in the form of a sorbic acid dip has aided in decay control of Bing cherries that otherwise are subject to *Aspergillus* and *Penicillium* infections. Some of the fresh commodities showing the greatest promise with this treatment are sweet cherries, tomatoes, pears, peaches, apricots, brocolli, and asparagus.

Dose rate is a factor which may prove important in the pasteurization of fresh fruits and vegetables as studied by the group at the USDA. Generally, a fast rate (70,000 rads/min) within a given range, gave more effective and consistent control of potato leak (Pythium debaryanum) than a comparatively slow rate (30,000 rads/min).

The importance of the individual organism involved in decay and its particular radio-sensitivity was emphasized, since two fungi of the same family grouping or two fungi causing identical rotting symptoms on the same suscept may show totally different responses to irradiation. A case in point is the suppression of Diplodia stem-end rot of oranges using 275,000 rads while a dose of 90,000 rads was sufficient for Phomopsis stem-end rot. Sour pit of peaches, (a yeast disease) and the causeal agent Torulopsis were partially inhibited at 150,000 rads while the insect vector, the common fruit fly, did not survive 100,000 rads 24 hours after irradiation.

A report concerning the potential value of large-scale testing for the preservation of food by irradiation was given by workers at the Denver and Rio Grande R. R. Company. Fresh peaches irradiated at 200-250,000 rads and subsequently stored at ambient temperatures (50-80 F.) in uniced railroad cars, remained in good condition for 20 days or more. These same doses were found optimal for effective decay control, least physiological damage and retention of appearance and taste qualities. Cold storage at 40 F. indicated a threefold increase in storage time beyond the 10-14 days normal period of holding.

The effects of irradiation on respiration changes in lettuce and apple tissue was studied at Cornell University. As determined by the evolution of CO_2 at 77 F., there is a marked stimulation of the rate of respiration in the case of lettuce. Immediately after a dose of 20,000 rads, there is a 50% increase in CO_2 production; the increase is 300% at a dose of 1 megarad. Within a matter of hours, CO_2 production returns to equal the control at doses up to 100,000 rads, while higher doses maintain their high CO_2 evolution for some 30 hours. With apple tissue there is an increase in the rate of respiration during irradiation at 1 megarad, while at intervals thereafter there is a proportional decrease in CO_2 production below that of the controls.

The potato sprout inhibition study at Purdue University was continued this year. It has been determined that a dose of approximately 5000 rads was sufficient to curtail sprouting on Sebago, Russet Burbank and Katahdin when potatoes were subsequently stored at 41°F., whereas the Red Pontiac variety required 7000 rads. Storage at 55° F. required 7,000 rads to curtail sprouting on all varieties tested with the exception of Red Pontiac; this latter variety required 9500-11,500 rads. Very little decay was noted in Russet Burbank tubers stored at 41° F. Decay tended to increase in direct proportion to dose in both Sebago and Katahdin when these were stored at 41° F., while at 55° F. only Sebago showed this tendency. Weight loss was less in the case of irradiated potatoes when stored either at 41° or 55° F. There was no advantage in defe irradiation if potatoes were to be stored at 47° F. or less.

ANIMAL PRODUCTS STERILIZED

Chairman: Dr. Hans Lineweaver

Research results concerning the sensory acceptability of radiation sterilized animal products were discussed. Organoleptic factors considered included odor, flavor, juiciness, texture, and appearance (especially color). Beef, pork, poultry, and fish products received most attention. As reported at last year's conference, pork and poultry products remain least altered by radiation. However, two laboratories found radiation sterilized oysters to be superior to canned oysters.

No consideration was given to combined low level radiation and heat processing. The heat treatment required generally gives an over cooked product even though it is less so than the straight heat processed product. On the other hand, heat treatment for enzyme inactivation remains essential for sterilized products, and progress on times and temperatures of treatment required for inactivation were reported for beef. Additional information is needed on specific items, such as pork and chicken. The treatment required gives essentially a cooked product, and this generally will lead to decreased juiciness. It is not yet certain that the minimum heat treatment for enzyme inactivation will be best for all organoleptic qualities.

Heat treatment tends to predispose meats to oxidation and rancidity. Antioxidants were reported to retard or prevent rancidity development if intimate mixing with the product is possible. This accelerated oxidation occurs rapidly, and may become significant between the time cans are opened and used.

It seemed generally agreed that vacuum packing should be used because of hydrogen-swell possibilities as well as to reduce the available oxygen. The effect of in-package odor scavengers appears to be of only limited value, being particularly effective in improving the odor upon initial opening of the can.

Further information is needed on changes during room temperature storage; quality as indicated by odor and flavor appears to improve slightly at first and then to decrease slowly. This observation indicates that quality changes during storage are less important than quality changes in the initial irradiated product.

The increased changes produced by increasing doses show the need for establishing the minimum safe irradiation treatment. Such an established minimum radiation dose requirement will expedite and help to consolidate acceptability studies, also.

Odor and taste tests by trained panels established that irradiated animal products are altered even at doses far below the 4.5 megarads level, and that the changes due to irradiation increase with dose. Untrained and consumer-type panels frequently fail to reveal these differences, yet there seems to be no question that radiation sterilized products are changed. The significance of the changes produced, therefore, is not clear.

Variations in panel procedure are the most likely cause of differences between the organoleptic results obtained in different laboratories. The "homogeneous sample" test participated in by 10 laboratories demonstrates that uniform results are possible and that acceptance tests related to hedonic tests should not be used to establish whether a detectable change was produced. It was pointed out that the untrained panel member responds as if he considers a rather wide range of flavor differences to be in the normal and therefore acceptable range.

Continued and additional acceptance tests are needed to clear up uncertainties as to whether the consumer would begin to recognize and reject irradiated products when these are presented again or a number of times. The view points of the conservative and optimistic camps on acceptability can only be resolved by thorough and rather elaborate tests. While color was not considered to be as critical as flavor and odor in acceptance, information on the effects of appearance, juiciness and texture factors should also be obtained.

Little attention seems to have been given to cooking or table preparation procedures. Thus, should radiation sterilized products be cooked slow, fast, covered, open, or in any special way to give the best product? Studies in this area are therefore also needed.

LONG-TERM DOG AND MONKEY FEEDING EXPERIMENT ON STORED IRRADIATED FOODS

Chairman: Dr. Frank R. Blood

The session consisted of progress reports presented by Contractors engaged in the evaluation of the wholesomeness of foods subjected to various levels of irradiation. Foods were irradiated at 2.79 and 5.58 megarads and stored for a minimum of three months. A control diet containing unirradiated food was included in all tests. The foods will be fed for two years and, unless otherwise stated, are incorporated in the diet at a level of 35% of the solids.

Dr. H. D. Alexander of Alabama Polytechnic Institute reported dogs have been fed cooked codfish and sweet potatoes for eighteen months. There have been no harmful effects resulting from the feeding of these foods.

It was reported by Dr. Blood from Vanderbilt University that beagles had been fed rations containing either boned chicken, ground beef or pineapple jam for one year. The animals fed the jam diet have glycosuria, which is undoubtedly the result of feeding a diet high in carbohydrate. No adverse effects due to incorporation or irradiated foods in the diet have been observed. Rhesus monkeys have received diets containing peaches, whole oranges or peeled oranges for one year. In order to obtain a diet acceptable to the monkeys, it was necessary to reduce the level of peeled oranges to 25% of the total ration solids. All oranges were irradiated at a level of 150,000 or 300,000 reps. Intraocular pressure has been determined on all monkeys, but there appears to be no effect attributable to the feeding of whole oranges. No difference in response of animals fed irradiated food as compared to those fed non-irradiated food have been observed.

Dr. R. W. Engle of Virginia Polytechnic Institute has fed shrimp and carrots to dogs for eighteen months. There are no detectable differences due to feeding irradiated shrimp or carrots in growth, reproduction or lactation.

Bacon and cabbage slaw have been fed to beagles by Dr. M. W. Hale of the Georgia Coastal Experimental Station. After twenty months on the bacon-containing diet, all dogs are doing well. Cabbage, irradiated at 0.279 and 0.558 megarads, was incorporated in the ration at 20% of the total solids and the experiment has been in progress for a year. Animals receiving cabbage irradiated at the 2-X level have a lower food consumption than the dogs fed the other levels of irradiation or the control diets. No explanation for this difference was given.

Results of the tests in which green beans and food compote were incorporated in the diet fed to beagles over a period of fifteen months were reported by Dr. P. S. Larsen of the Medical College of Virginia. No pattern of effects relatable to irradiated food are apparent in growth, food effeciency or reproduction.

Nutritional and toxicological studies on dogs fed irradiated dried whole eggs at a 20% level in their diet for the past four years have been continued at Massachusetts Institute of Technology by Drs. D. E. Proctor, S. A. Goldblith and S. A. Miller. There is no direct evidence of nutritional or pathological toxic phenomena caused by feeding irradiated whole dried eggs.

Dr. J. L. Radomski of the University of Miami School of Medicine reported that after seventy-two weeks of feeding evaporated milk and fifty-five weeks of feeding beef stew (C-ration) to dogs no toxic effects ascribable to the irradiated foods have been observed.

Dr. E. F. Reber, University of Illinois College of Veterinary Medicine, reported that beef and flour have been fed to dogs for eighteen months. There was a significant decrease in consumption of beef ration, which amounted to 995 grams per megarad of irradiation when food consumption was adjusted for variation in the initial weights of the dogs. No other adverse effects were observed due to feeding of irradiated beef or flour.

At Cornell University Dr. C. M. McCay has fed pork, potatoes, corn, chicken stew and tuna fish to dogs. Frozen raw beef irradiated by the Vande Graff equipment with 3 and 6 megarads was fed in a ration containing 33% of irradiated beef on a dry weight basis. During the three-year experimental period there was evidence that reproduction was poor for groups fed irradiated beef. Tissues of these animals are now being examined by the Histopathologist.

In summary, all Contractors have fed the test foods for at least one year and there are no apparent manifestations of toxicity due to irradiation of the test foods. Feeding of irradiated food has not altered the blood hemoglobin content, red and white blood cell counts or differential counts in any of the groups. Most of the studies are in the reproduction and lactation phase and it is too early to make an evaluation.

University of Colorado
USA MED R&N Lab.

Official Investigators:
Witt, N. F., Plough, I. C. et al

Title: Current Status of Human Feeding Experiments on Irradiated Foods

Chairman: Lt. Col. L. M. Hursh

Objective

To determine the safety for human beings of foods sterilized by ionizing radiation.

Progress

Previous studies have shown that humans who consumed diets containing some 40 foods, sterilized by ionizing radiation and stored frozen until use, suffered no ill effects. In the past 20 months, similar tests have been performed with 19 foods sterilized by radiation and stored at room temperature for at least 2 months before consumption. There were no ill effects from these foods, which were fed for periods of 15 days only.

Significance of Work

There appears to be no toxic effects in humans from the consumption of radiated foods over short periods of time. Long term feeding tests will be started in the near future as a final test of the safety of radiated foods.

NUCLEAR EFFECTS

Chairman: Dr. Paul Kruger

The session on Nuclear Effects, was held 28 Jan 59 from 2 to 5 PM. The program was originally scheduled to have the contract investigators review the results of their work, and be followed by general discussion in the two general nuclear effects areas covered in the QMFCI program, (1) Induced Radioactivity resulting from sterilizing irradiations, and (2) Dosimetry and Dose Distribution. Because of the extensive material on Induced Radioactivity presented by the contractors and the lively discussion on the definition of an "insignificant" quantity of induced radioactivity, the entire session was devoted to the subject of Induced Activity and and extra session was scheduled for 9 PM, for discussion of Dosimetry, to be led by Dr. S. Taimuty of Stanford Research Institute. This summary report, therefore, covers only the subject of Induced Radioactivity resulting from sterilizing irradiations.

The presentation of results by investigators consisted of reviews of the problems, modes of investigation, experimental data, and evaluations by the senior investigators of the two groups under contract with the QMFCI; Paul Kruger NSEC and Dick Glass, SRI. Since the details of these programs are covered in recent progress reports to the QMFCI, only the salient points are summarized in this report.

Dr. Kruger reviewed the neutron production and induced radioactivity problems associated with the several types of irradiation facilities currently being used by the QMFCI. These facilities include Co^{60} sources, spent fuel element γ-irradiation facilities, and electron linear accelerators. Since the nuclear characteristics of these types of facilities are different for each facility, each was examined individually.

Based upon the data from the Dugway Proving Grounds Co^{60} source, and the limitation of the Co^{60} γ-radiation to produce neutrons, the activation problems of these sources were considered unimportant.

The photoneutron production resulting from the interaction of the fission product 12.8-day Ba^{140}- La^{140} with deuterium in natural water in the spent fuel element γ-irradiation was reviewed. The neutron flux measurements made at three facilities were reviewed. Although the fluxes ranged from 7 to 1400 n/cm^2sec at these facilities, the amount of radioactivity produced w below detectable levels. Calculations of expected radioactivity from chemical analytical data for several representative foods with the measured neutron fluxes yielded expected activity levels sufficiently small to be undetectable.

Data for the neutron fluxes and activation in linear accelerators were divided into three electron energy groups, low (2-3.5 Mev), medium (6-8 Mev), and high (>15 Mev). Correlations of the neutron fluxes and activation in

homogenized chicken and tin plate containers with these electron energy groups were reviewed. Below 8 Mev, neutron fluxes were small, and of the same order of magnitude as these in the spent fuel elements γ-irradiation facilities. Neither short-lived nor long-lived activities were observed in the chicken and tin plate even when irradiated to hundreds of Megarads of electron radiation. The high energy machine (>15 Mev) yielded considerably greater neutron fluxes. Short-lived activities were observed in both the chicken and tin plate. Analysis for long-lived activity by low-level radioactivity detection equipment 60-90 days after irradiation, however, resulted in less than detectable levels of radioactivity.

Review was then made of future work to correlate more accurately the neutron fluxes and activation levels with electron energy at the General Atomic linear accelerator which is both a high energy and high intensity machine, and with neutrons by high neutron flux irradiations at a national reactor site.

Dr. Glass reviewed the program underway at SRI to study in more detail the induced activity problems associated with a 24-Mev linear accelerator, the energy tentatively set for the Stockton, California production prototype machine. Calculations were developed to obtain values of γ-induced radioactivities from a theoretical understanding of electron interactions. Dr. Glass expects to be able to set up for computer operation, routine methods for deducing expected activation levels for the various parameters of electron irradiation.

Review was made of the work in progress to measure the induced activity from two hazard viewpoints, (1) handling and environmental radiation fields, and (2) ingestion. Irradiations were made of beef packages, and the radioactivity associated with 30 cc of sterilized beef was examined. Radioactivity decay analysis showed the presence and the levels obtained of the short-lived activities resulting from the irradiation oxygen and carbon. Discussion of the other important contributions to the total activity level was made.

Dr. Glass reviewed the dosimetry problems associated with the accelerator irradiations and presented the data obtained from polyvinyl chloride film exposures, showing the intensity and geometry of the radiation field.

Dr. Glass also reviewed the program in which the sensitivities of measurement for the important γ-induced radioactivities, notably Na^{22}, can be increased by enriching food specimens with the pure elements. An analysis was presented of the relation of the induced levels of radioactivity to the existing levels of radioactivity due to K^{40} and other naturally-occurring radioactivity and to Sr^{89} and Sr^{90} from British analyses of milk samples.

Following a general discussion of these two presentations, the remainder of the session was devoted to the problem of defining what constituted an "insignificant" quantity of induced radioactivity.

A review was made by group discussions of the philosophies behind the QM program in terms of military emergency, military economy, and public usage of irradiated foods. It was considered beyond the scope of this session to evaluate these philosophies. The chairman confined the analysis to the problem of physical interpretation of the induced activity data, recommending that medical and legal interpretation be left for those more qualified to render interpretation on these matters. A fourth consideration was later added, namely that of economics and expediency. The final consideration of the success of food irradiation for presentation then must be considered for the induced activity problem from at least four points of view:

(1) physical interpretation of whether radioactivity in food is induced or not, the physical limitations of sensitivity of measurement, and the correlation of any induced activity with irradiation conditions.

(2) the medical interpretation of whether any induced activity is biologically acceptable, and if some is, at what levels.

(3) the legal interpretation of whether irradiated food will be accepted as a non-hazardous material and,

(4) the business and expediency interpretation of the conditions under which it is desirable to have food preserved by irradiation.

Since only item (1) was of concern to the session, this report covers the pertinent discussions held on the physical interpretations. There are two possible areas of interest under this item:

(a) if induced activity cannot be measured, and

(b) if induced activity can be measured.

More agreement was obtained on the latter situation. Where activity levels can be measured, the best information available can be presented as fulfillment of item (1). The remainder of evaluation of the induced activity problem is then beyond the physical interpretation. Data can be obtained to correlate levels of induced activity with facility type and energy of incident particles. For any "allowable" level of activity the irradiation conditions can then be specified.

The former situation, where no activity is measurable, was considered more complex from the physical point of view. Within some physical limit of detection ability, irradiated foods may be said to be free of induced radioactivity if the statistical variation of background radioactivity is larger

than the levels of induced radioactivity. For this case, the physical interpretation may be confined to an analysis of the variations in backgrounds in food and the sensitivity of the best detection systems available.

Work is in progress for both of these considerations, (1) to correlate induced activity with type and energy of irradiation and (2) to increase as far as possible the sensitivity of non-detectable limits. Data from other completed work outside the QM program should be included.

The meeting terminated without clear-cut decisions, but with a better understanding of the problems involved, as far as they pertain to Nuclear Effects.

NUCLEAR EFFECTS

Chairman: Dr. S. I. Taimuty

This session was devoted to two presentations, one by Dr. Taimuty on "Obtaining A System of Dosimetry" and another by Dr. Frank Hoecker on "High Level Radiation Polymerization Dosimetry". Time did not permit for Dr. Donald Young of General Mills, Inc., to make his presentation, however, some of his work is reported here.

The objectives of the Stanford Research Institute program are: (1) to develop an integrating dosimetry system which can serve as a working standard in the QMC program for doses of 10^4 to 10^7 rads with gamma and electron beam sources; (2) to develop a production monitoring system for gamma sources with dose rates up to 10^7 rads/hr; (3) to develop a production monitoring system for high intensity electron beam sources.

After a thorough literature search and experimental evaluation of promising dosimetry systems, a two-component system consisting of the cobalt (F-0621) glass dosimeter and the ceric sulfate dosimeter was chosen. The glass dosimeter was chosen for primary use at doses of 10^4 to 10^5 rads and for secondary use at higher doses. The ceric dosimeter was chosen for primary use at doses of 10^5 to 10^7 rads. Standard procedures for using these dosimeters have been developed.

A spherical graphite ionization chamber was developed to serve as a gamma source production monitor. The chamber and the first 3 feet of connecting cable are constructed of radiation-resistant inorganic materials so that long-term, continuous exposure to radiation will be possible. Guard-ring construction eliminates radiation-induced leakage currents from the measuring circuit. Chamber voltages under 600 volts insure saturation collection of the ionization current at dose rates up to 10^7 rads/hr.

An electron beam production monitoring system, consisting of separate current and energy monitors, has been developed. The current monitor functions by collecting, in vacuo, the low energy secondary electrons emitted from the surfaces of a thin metallic foil through which the high-energy primary beam is transmitted. The secondary electron current is a constant fraction of the primary current for beam energies in excess of approximately 0.5 Mev. The energy monitor is a device for making a continuous measurement of the range of the primary beam in aluminum. A small portion of the beam is absorbed in a stack of thin foils insulated from each other, and the number of electrons that stop in each foil is measured continuously. The energy can be derived by extrapolation of the straight-line portion of the curve of current versus foil thickness. Constancy of energy can be monitored by measuring the ratio of currents collected by two adjacent foils near the end of the range.

The techniques developed in this project provide the Quartermaster Food and Container Institute with dosimetry and production monitoring systems which can provide baseline measurement techniques and information for use in production specifications. In addition, the dosimetry systems which were developed can be used to provide uniformity in procedures throughout the QMC program.

It has been shown by Dr. Frank E. Hoecker that (1) a go, no-go type of high energy radiation dosimeter can be made by utilizing a polyester liquid whose composition may be altered in such a manner that a wide range of radiation doses may be accurately detected. This dosimeter uses infinite network (gel phase) formation as the index to indicate the absorption of the design dose.

The dosimeter has been made in several forms, one of which consists of a No. 000 gelatin capsule containing approximately one cc of liquid, a lead sphere and/or a bubble. When used to study the radiation response of the dosimetric liquid, these cells are exposed with long axis vertical. Gelation (and hence the dose end-point) is observed by partially or completely inverting the cell to detect motion or lack of motion of the bubble and/or lead sphere. Exposure to isotropic radiation produces uniform gelation; exposure to non-isotropic radiation incident parallel to the long axis of the cell results in progressive gelation along the axis, the extent of which permits the use of one cell to cover a range of doses. No auxiliary equipment is needed to read the result and it may be read by entirely untrained personnel since the only observation required is whether or not motion of the bubble and/or sphere occurs upon inversion.

On the basis of experiment (2) it is observed that the dosimeter responds to all energies of x-and gamma-rays over the range of less than 100 K.V. through Co-60 and fission product radiation. Experiments with beta-radiation from a resonance accelerator show no dose rate dependence over a range from 30 to 1000 kilorads per minute. The dosimeter response is known to be independent of temperature during exposure between 0° and 40° C. The coefficient of absorption of the liquid measured with x-rays filtered with 0.55 mm of Cu is the same as that of soft tissue.

Dosimeter cells have been prepared for any desired dose between 5×10^4 and 5×10^6 rad. They have been designed in the form of a flat disk $\frac{1}{4}$ inch thick and 5/8 inch in diameter in which the container is polyethylene. This type may be attached to any ordinary tinned food container as it is passed through a radiation field for preservation. The cell will indicate whether the required preservation dose has been delivered.

Refinements and variations of this dosimeter are now under development for use in connection with radiation preservation of all kinds of food.

52249 O—60—pt. 1——20

According to Dr. Donald Young, the dose measuring devices under investigation include an ionization chamber, adiabatic calorimeter, and the blue cellophane-dye system. The ionization chamber is small, easily fabricated, simple to use, and allows rapid reproducible dose measurements to be made in a cobalt-60 source. The calorimeter is more difficult to make and use, but serves as an accurate, absolute method of dose measurement. The humidity and temperature dependence of the cellophane-dye system have been investigated and controlled to improve the accuracy of the cellophane-dye dosimeter. Subsequently, the cellophane dosimeter has been used to measure the magnitude and extent into the product of "surface burn", the anomalous high dose in a product near the wall of a tin can irradiated in spent uranium fuel rod radiation sources.

Due to the length of the evening session (2½ hrs.), the meeting was terminated without a discussion period. However, it was the consensus of opinion that a great deal has been accomplished in this area.

ANIMAL PRODUCTS PASTEURIZED

Chairman: Dr. R. L. Henrickson

The primary purpose for the application of low irradiation doses is to provide extended shelf life to fresh animal products. This in general seems to reduce the initial microbial load. Discussion was devoted to the relationship of total numbers of microflora to such contaminants as type E Clostridium botulinum, staphylococci, and Streptococci. Total microflora present constitute a problem which may influence both the quality of the product and its aesthetic value. It was noted that a 200,000 rad dose will reduce the total count by more than 90%. The product was acceptable as long as 6 weeks after storage.

Present findings would indicate that the threshold for the production of irradiation flavor is about 50,000 rads for beef, 100,000 rads for pork, 100,000 for poultry, and for fish 100,000. Odor was considered to be another problem, but the general feeling of the group indicated that the threshold levels may be about the same as those for flavor. Some indication was given that the flavor threshold level may be as high as 400,000 rads.

Reports indicated that further work would be needed on such items as chicken, beef, and pork pies before pasteurization dose levels of irradiation would have practical use. Thinning of the gravy was considered a problem. Toughening of the meat was noted. Contaminants such as mold were also recognized.

It was generally agreed that low dose levels of gamma irradiation would extend the shelf life of animal products. Fresh vac-packed pork sausage was acceptable at 0.2 and 0.4 megarads and the shelf life was extended as much as 20 days.

Recognition was given to the original source of meat items used for irradiation. Since wide differences might occur in the kind of product one might choose for experimentation, it may be well to characterize the product being used. Such differences as age of animal before slaughter, condition, as well as, pre- and post- slaughter variables may be of significance in the development of a product. Meat from animals having a high pH was recognized as an area requiring further work.

The effect of adding chemical compounds, gravy, and sauces to meat and poultry items to reduce the adverse flavor was recognized. Considerably more work is needed with masking agents before their practical value can be determined.

CURRENT STATUS OF PROGRAM ON TISSUE AND BLOOD ENZYMES AND EFFECT OF IRRADIATION ON ALLERGENICITY OF PROTEINS

Chairman: Ian J. Tinsley

The studies reported in this section were concerned with the tissue and blood enzymes of animals ingesting irradiated foods. The basis for these studies was the fact that alterations in enzyme activity might be preceded by changes in cellular metabolism.

Studies in progress at Ohio State University (R. O. Moore) are concerned with the ability of digestive enzymes to attack irradiated macronutrients. In vitro experiments have shown that irradiation had relatively little effect on the digestion of carbohydrates, improved the digestibility of undenatured proteins for those proteinases normally acting on denatured proteins, and depressed the digestibility of fats by alimentary lipase. Storage of the irradiated substrates did not produce any additional effects. Feeding experiments using the same irradiated products are now in progress.

It has been shown (O. Rosenthal) that irradiated beef (5.6 megarad) and irradiated beef stored for 3 weeks at 37° C were as effective as the unirradiated product in restoring enzyme activity and total protein of the livers of protein depleted rats. Intact animals as well as rats subjected to partial hepatectomy at the end of the depletion period were employed.

Rats fed a ration containing irradiated pork showed a decrease in activity of erythrocyte transketolase and serum transaminase (A. Ostashever). These effects were specifically overcome by supplementing the ration with thiamine and pyridoxine respectively.

A ration of irradiated pork or irradiated beef has resulted in an increase in the liver cytochrome oxidase of rats. This increase has also been shown to occur in heart and kidney tissue (I. J. Tinsley). Recent work at the U. S. Army Medical Research and Nutrition Laboratory (M. S. Read) designed to elucidate the mechanism of this change has implicated the lipide content as well as the vitamin K content of the ration. However, the exact nature of this phenomenon is not yet understood.

Using rats fed a composite diet of irradiated shrimp and oranges, studies have been made on the activity of enzymes of the intestinal tissue (A. W. Phillips). The enzyme activity of intestinal tissue of animals on the irradiated diet appeared to be somewhat lower in some cases than in the control animals.

Increased levels of irradiation (0.456-9.30 megarad) increases the mean lethal shocking doses for irradiated milk samples when challenged on milk sensitized guinea pigs (H. F. Kraybill). Comparative data have also been obtained on heat processed milk samples as well as those irradiated with ultra-violet light.

A brief outline was given of a study recently initiated at U.C.L.A. (J. F. Mead) concerning the composition of the brain lipides of aging rats on irradiated and control rations.

To date, no gross changes in cellular metabolism have been observed in animals fed rations containing irradiated foods. In some cases the decrease in enzyme activities associated with the ration containing the irradiated food have been shown to be due to a lower level of a vitamin in the ration. Vitamin supplementation restores the enzyme activity to the level observed in the control. It would appear that the elevation of cytochrome oxidase activity is associated with the metabolism of irradiated lipides and their interaction with the fat soluble vitamins.

THE HEMMORHAGIC DIATHESIS SYNDROME

Chairman: Dr. B. Connor Johnson

The induction of fatal hemmorhages in rats fed irradiated beef was previously reported by the University of Illinois group and has been confirmed by two other laboratories but not reproduced by three additional laboratories. This may be due to strain differences in the rats used. It has been shown that irradiated or even cooked non-irradiated pork brings about the same syndrome. The original observations that vitamin K added in adequate amounts will prevent the hemmorhagic diathesis has been confirmed as has the observation that the male rat is much more susceptible than is the female rat. Work at the Medical College of Virginia has shown that this susceptibility is indeed sex-linked in that castrate males are no longer as susceptible while castrate females are more susceptible than the respective controls.

It has been found that carbonyls, such as those produced in meat irradiation, when added to non-irradiated beef, cause hemmorhages to be produced.

To understand the reasons apparently involved in the production of this disease, it seems most important to understand the nature of vitamin K nutrition of the rat. It has been "known" for many years that the rat does not require vitamin K in its diet, and that the reason for this is that the rat is able to obtain its vitamin K from intestinal synthesis (e.g. this K synthesis can be prevented by sulfa feeding). It has also been shown that fat soluble vitamin K in the diet is directly absorbed from the tract along with other fats (bile fistula animals come down with vitamin K deficiency). However, the work reported here from the University of Illinois indicates that the intestinal synthesis of vitamin K is available to the rat only by coprophagy; apparently the synthesis takes place low in the tract and probably the vitamin K so made is intracellular in the bacterial cells. It has been found that rats on a diet of beef irradiated to 6 megarads do not practice coprophagy, and this, along with destruction of vitamin K by irradiation appears to be the basic reason that rats on such irradiated beef develop prolonged prothrombin times, (low prothrombin levels) and eventually die of hemmorhagic diathesis.

It appears that absorption of intestinally synthesized vitamin K is not involved in that fat soluble or water soluble vitamin K when fed are equally available.

In addition to these observations, there are suggestions that other factors (vitamin E, levels of other components of the coagulation mechanism not effected by vitamin K., etc.) may be involved.

It would appear that a great deal has been learned about how the rat normally gets vitamin K but it is obvious that this does not aid in our knowledge of vitamin K nutrition of man. Does man require a dietary source (if so, then irradiated beef, or foods or vitamin K, is no different than the picture with regard to any other vitamin sensitive to radiation) or can man obtain his vitamin K by intestinal synthesis and direct absorption (since man does not practice coprophagy?) If this latter is the case, would irradiated beef or pork have any effect, or is the whole answer in the refusal of the irradiated meat fed rat to eat his feces as voided?

In this connection it was reported that there was no difference in the vitamin K content of feces from non-irradiated and from irradiated beef fed rats.

The carbonyl effect was again found to be due to their bringing about a reduction in coprophagy.

THE WHOLESOMENESS OF IRRADIATED FOODS

Dr. H. F. Kraybill
U. S. Army Medical Research and Nutrition Laboratory

The program on "Wholesomeness of Irradiated Foods" supported by the Office of The Surgeon General, Department of the Army, was initiated in early 1954 through the support of contracts at several research institutions. In the earlier work in the program, the toxicological investigations were concerned with short term animal feeding experiments (subacute toxicity) on irradiated foods stored frozen. These experiments were designed for the purpose of providing toxicity clearance on representative irradiated foods to be tested by palatability panels at the Quartermaster Food and Container Institute for the Armed Forces, Chicago, Illinois, and for subsequent trials on the human volunteers in the Metabolic Ward at our laboratory. Long term rat feeding experiments were soon instituted to provide chronic toxicity data, providing ultimate clearance for testing these foods on human volunteers for periods of several months.

A few years ago the program was recast into the screening of irradiated foods that had been stored at 70° F. for minimum periods of 3 months. In addition to testing foods that were irradiated at 3 megarep (an arbitrarily selected sterilizing dose), foods were also tested that received a radiation dose of 6 megarep. The latter radiation dose, or 2X treatment, was introduced into the experimental design of animal feeding experiments as a safety factor encompassing all higher radiation doses that one might encounter in practical radiation processing of foods. The current animal feeding experiments are based on the testing of a broad spectrum of irradiated foods stored at 70° F. for at least 3 months. The test animals used are the rat, dog and monkey, with the long term experiment requiring a minimum period of 104 weeks. A group of 21 foods was selected for testing, each food being a representative member of the following classes of foods: a) meats, b) fishery products, c) milk products, d) vegetables, e) fruits, and f) cereal products. In this research program, the foods were selected as being typical of a class; for example, green beans, a type of leafy green and yellow vegetable, etc., and not necessarily that each item was of major importance to the Department of the Army as a ration item.

The list of 21 foods that are currently fed to rats, dogs and/or monkeys for the 2-year period is as follows:

1. Beef, ground
2. Pork loin
3. Bacon
4. Beef stew
5. Tuna
6. Shrimp
7. Codfish
8. Chicken, boned
9. Chicken stew
10. Cabbage
11. Carrots
12. Beans, green
13. Potatoes, white
14. Potatoes, sweet
15. Corn
16. Flour
17. Fruit comp
18. Jam, pine
19. Peaches*
20. Oranges*
21. Evaporated

* Nineteen of the foods are fed to dogs; peaches and oranges are fed to monkeys as the test animal. Oranges are fed to rats and monkeys both as the whole orange and peeled orange to test the possible toxicity of the irradiated orange peel.

In such a broad program of testing for the wholesomeness of irradiated foods, a certain delineation of areas of research is desirable for evaluating the nutritional adequacy and toxicity, if any, of these foods. The projects and efforts of investigators have therefore been classified as follows:

1. Short term (subacute toxicity) feeding experiments - 8 to 12 weeks.

2. Long term (chronic toxicity) feeding experiments - 104 weeks.

3. Nutritional adequacy experiments - Comparative studies on raw, heat processed and radiation processed foods to determine effect on the macronutrients and micronutrients.

4. Carcinogenicity experiments - Determination of the effect of radiation processing on formation of potential carcinogens, if any, in foods. Comparisons are made as to the relative rate of tumor formation in rats or dogs fed irradiated and nonirradiated diets.

5. Blood and tissue enzyme research - Determination at the cellular level whether feeding irradiated foods to experimental animals alters certain metabolic pathways as reflected in tissue and blood enzyme activities.

6. Histopathology examinations - At termination of the long term rat, dog or monkey-feeding experiments, comprehensive data as to the effect of the diet (containing any potential carcinogens or toxic compounds) can only be secured by extensive post mortem examination of the tissues. This work should require 12 to 18 months of investigation following the termination of the feeding experiment.

7. Human feeding experiments - The possible toxicity of irradiated foods is evaluated through feeding studies on human volunteers at the U. S. Army Medical Research and Nutrition Laboratory, Fitzsimons Army Hospital. Acceptability information is obtained in large scale human feeding trials on troops such as those currently conducted at Fort Lee, Virginia.

8. Special areas of research

a. The problem of hemorrhagic diathesis encountered in the feeding of irradiated beef to rats was investigated during the past year. It became necessary to elucidate the mechanism of the vitamin K destruction and the production of the hemorrhagic syndrome in order to

ascertain whether radiation processing of foods contributed to the hemorrhage or whether this was an artifact of diet.

b. Alteration of food proteins by ionizing radiation can be studies by biological as well as chemical procedures. The change in anaphylactogenic properties of milk protein treated with gamma radiation has been studied within the last year, using guinea pigs as the test species.

CURRENT STATUS OF PROGRAM

1. Short term feeding experiments

During the past few years, approximately forty-four (44) foods have been cleared by the subacute toxicity experiments in which irradiated foods have been fed to rats for 8 to 12 weeks. From this group of foods, further extrapolation was made as to classes and types of foods to a list of 108 foods approved for study on humans for limited periods of testing.

2. Long term feeding experiments

A few of the irradiated foods that were stored frozen, such as pork and beef, have been fed to rats for the minimum period of 104 weeks. No significant differences were noted in the performance of these animals on either the irradiated or nonirradiated diets. To simulate actual practice, all of the irradiated foods that were stored at 70° F. were cooked prior to feeding. Of the 21 foods that have been radiation processed, stored and fed under these conditions to rats, only one food, irradiated pork, has been fed for 104 weeks. The minimum period that any irradiated food has been fed thus far is 20 weeks and this food is flour. Many of the foods in this group of 21 have been fed to rats and to dogs for approximately 75 weeks. In evaluating the data obtained thus far in the long term rat-feeding experiments, no major differences have been noted between the irradiated food diets or nonirradiated food diets insofar as growth, food consumption, longevity, reproduction or lactational performance are concerned.

In one study, a composite diet of irradiated foods which simulated the military field ration A in composition and in which there was no supplementation with vitamins, produced some decreased growth in rats after 30 days. Supplementation with thiamine did not correct the decrease in body weight, however, pyridoxine partially overcame the decrease in weight gain. Serum transaminase levels were decreased also in both the thiamine supplemented and unsupplemented diets. A diet consisting entirely of thermally processed food would probably produce a similar effect on rats fed this type of diet. Future work should establish whether heat processing produces similar effects on the micronutrients.

The group of 19 foods fed to dogs and the two foods fed to monkeys have not, thus far, shown any significant differences for the animals fed either the diets of irradiated or nonirradiated foods with respect to growth, food consumption, mortalities and reproductive or lactational performance. Irradiated pork has been fed to dogs for 104 weeks and the remainder of the foods has been fed for approximately 75 weeks. Only one food has thus far shown a reduced food consumption at the 2X radiation dose. Dogs seem to consume readily nonirradiated cabbage and irradiated cabbage at the 2.79×10^5 rad dosage at 20 percent solids level in the diet. However, for reasons of palatability, the dogs will not readily consume the cabbage treated at 5.58×10^5 rads.

3. Nutritional adequacy

Extensive animal feeding experiments have been conducted to determine the effect of radiation processing on the micronutrient and macronutrient content of the diet. While radiation treatment has some destructive effect on the vitamins, the percentage destruction is no greater, and in many cases not as great, as that observed by heat processing these same foods. The metabolizable energy value of a ration composed of irradiated foods was not different than the M.E. value obtained in feeding rats a diet of non-irradiated foods. Similarly, no significant difference was noted in the biological value of proteins whether irradiated or non-irradiated foods were offered to rats in some short term feeding trials.

4. Carcinogenicity studies

Comprehensive studies on foods and mixtures of foods were initiated in 1954 to determine whether radiation induced the formation of carcinogens. Some of the following foods have been examined: brain and egg sterols, beef and yeast sterol concentrates, meat, fish, cheese and milk mixture, lard and vegetable oils. These foods were selected on the basis of their sterol content with the possibility that radiation treatment of this compound might product potential carcinogens. None of these foods tested after several years on rats and mice by feeding, injection of concentrates or painting concentrates on the skin, has shown any diet-related tendency toward spontaneous tumor formation.

In the group of 21 foods, 12 are being investigated as to their carcinogenic properties. In one study, a diet consisting of pork, chicken, milk, carrots and potatoes, all of which were irradiated at 6 megarep, has been fed to mice for 48 weeks. In another study, the irradiated ration consists of codfish, chicken stew, beef stew, green beans, peaches and flour which was also fed to mice for 32 weeks. All of these foods have been stored for 3 months at 70° F. and cooked prior to feeding. These studies have not progressed far enough to yield any definitive results at this time.

5. Cellular activities of tissue and blood enzymes

Feeding raw or cooked room temperature stored irradiated beef produced a 25 percent increase in liver cytochrome oxidase in presence of corn oil in the diet. Leaving corn oil out of the diet resulted in no increase in liver cytochrome oxidase activity. Omission of vitamin K from the diet causes an increase in cytochrome oxidase activity for the unirradiated diet group of rats to a level comparable to that found in rats fed the irradiated beef diet. By omitting corn oil and vitamin K, no difference in cytochrome oxidase levels was noted in the rats fed the control or irradiated diet. Some decrease has been noted in choline oxidase levels in rat tissue when these animals were fed an irradiated pork ration. Assays made for transketolase and transaminase activities in rats fed an unsupplemented irradiated pork ration showed that there were decreases in the levels for these blood enzymes.

Preliminary experiments with feeding irradiated shrimp and orange diet to rats showed a significant decrease in the activity of enzymes in the duodenum of the rats under test.

Irradiation apparently has little effect on the digestibility of carbohydrates in in vitro studies. Irradiation on the other hand improved the digestibility of undenatured proteins, but depressed the digestibility of fats by alimentary lipase.

These findings -- obtained on the activities of certain tissue and blood enzymes and demonstrating the role of specific vitamins and the macronutrients -- parallel previous findings observed on the destruction of the vitamins.

6. Histopathology investigations

Since most of the feeding experiments have not approached the terminal period of 104 weeks, a complete report on this work cannot be furnished at this time.

7. Human feeding experiments

Paralleling the animal feeding experiments on irradiated foods are those with the 10 human volunteers at the U. S. Army Medical Research and Nutrition Laboratory (Denver, Colorado). Three studies have been conducted on these foods, resulting in the extensive investigation of nineteen (19) foods to date. In the 30-day experiment, the human test subjects divided into groups of 5 are rotated on the control and irradiated diets. The maximum period that a test subject receives the irradiated food is 15 days. Since the irradiated food constitutes 80 percent of the total calories of the diet, this represents a rather critical challenge in testing for toxicity.

All bacteriological tests conducted thus far on the irradiated foods given to the human volunteers have failed to reveal the presence of any Clostridium botulinum or toxin. Clinical examinations such as chest x-ray, kidney function and liver function tests and hematological data on the test subjects prior to and after the feeding experiments have failed to reveal any untoward effects as a result of ingestion of these foods.

Future tests on these foods will be conducted with the view toward feeding these irradiated foods for extended periods of 3 to 6 months.

8. Special areas of research

a. Alteration in anaphylactogenic properties of irradiated proteins.

Gamma radiation of milk protein has been shown to be quite effective in reducing the allergenic properties of skim milk proteins. These alterations have been quantitatively measured biologically by means of gross anaphylaxis measurements and uterine strip contractions on milk sensitized guinea pigs. Radiation doses of 2.79, 5.58 and 9.30 megarads applied to milk protein yielded LD_{50} values of 64, 602 and 1157 gammas of protein nitrogen compared to an LD_{50} value for unirradiated milk of 32 gammas of protein nitrogen. The 9.30 megarad radiation dose produced a 31-fold change, biologically, in the response of this irradiated milk sample. Whole milk irradiated with a Cobalt-60 source and concurrently distilled according to the method developed by Proctor, et al. at Massachusetts Institute of Technology, resulted in a milk product with reduced allergenic properties and was quite an acceptable product from the standpoint of color, odor and flavor.

b. Production of hemorrhagic syndrome in rats fed diet of irradiated beef.

The mechanism of the induction of the hemorrhagic syndrome in male rats fed irradiated meats has been studied in several laboratories. Animals fed irradiated beef do not practice coprophagy which normally serves as a source of vitamins, particularly vitamin K. The spontaneous hemorrhage which occurs in these animals may be prevented by oral administration of menadione (K_3). Experimentally, it has been shown that n-decyl aldehyde may induce the hemorrhagic diathesis in rats, proving that carbonyl type compounds may be associated with the vitamin destruction.

Irradiated beef, when stored at elevated temperatures, will also increase the induction of the hemorrhage as will also cooking irradiated meat. These findings have not been restricted to beef since the onset of the disease occurs more rapidly with pork than with beef. Cooked fresh pork also causes hemorrhage to a marked degree. Female rats do not demonstrate the same tendency toward the hemorrhagic syndrome as male rats. Low levels of prothrombin and accelerator globulin occur in all animals exhibiting the hemorrhagic diathesis. Increased hemolysis of erythrocytes suggests a possible involvement of vitamin E deficiency in this disease state.

CONCLUSIONS

In the investigations conducted over the past few years, irradiated foods stored frozen or at 70°F., when fed to experimental animals or man have not thus far shown any toxic properties. No evidence has been obtained to date to establish that radiation processing of foods induces any carcinogens on the basis of experiments conducted with mice and rats. While ionizing radiation does have some destructive effect on the vitamins including vitamin K, the loss in nutrients observed is no greater than that noted from thermal treatment of foods. Final evaluation of the wholesomeness of these foods, however, must await the completion of the long term animal feeding experiments and the more extensive testing of these foods on human test subjects for periods of 6 to 9 months.

RADIATION PRESERVATION OF FOODS PROJECT

Harry E. Goresline, Deputy Scientific Director
Quartermaster Food and Container Institute for the Armed Forces
Chicago, Illinois

The Radiation Preservation of Foods Project was initiated in 1953 with the mission of determining the feasibility of using ionizing radiation for the development of a new food processing system. Some reasons for this are as follows:

1. As early as 1899 it was known that ionizing radiation could be employed to kill bacteria.

2. The practical potential for using such radiation was enhanced by development of radiation sources, particularly fission sources and electron accelerators.

3. The small rise in temperature within the product during radiation raised the possibility that an alternative system to thermal processing might be possible and might be advantageous.

Consequently, most of the first year's efforts were devoted to survey-type investigations of the effects of irradiation on whole foods and food components. Almost immediately in this survey experimentation certain types of foods were found to be sensitive to irradiation. The magnitude of discoloration, off-flavors, and unappetizing aromas in dairy products and formulated meat items (bologna, frankfurters) almost eliminated them from early consideration as end products. Beef was shown to have the greatest degree of "off-odor/flavor" of radiation-stabilized meats, and softening of texture was shown to be a basic undesirable change occurring in fruit and vegetable products.

In the past year the emphasis in the project has been shifted to the development of specific food products. Accordingly, I should like to point my remarks on the history, status and objectives of the Project, to specific elements of A FOOD IRRADIATION PROCESS as it is outlined very broadly here: RAW MATERIAL - FOOD PROCESSING - PACKAGING - RADIATION PROCESSING - PRODUCT

As an example of a specific product carried through a process, I should like to use white potatoes. The research on this process that we can do in the Institute program is nearly complete.

RAW MATERIAL - It is best to use thick-skinned varieties, such as Maine Katahdin and the Idaho Russet, which have been well cured.

FOOD PROCESSING & PACKAGING - Do not apply.

RADIATION PROCESSING - Optimum dose range for sprout-inhibition is between 7,000 and 8,000 rads depending upon variety. The research has been done with gamma radiation. Use of electrons in a pilot plant type run remains to be accomplished.

ACCEPTABILITY - When stored at 41° F., 85% relative humidity, potatoes have come through 21 months of storage, while at 55° F., the successful storage period was about 18 months. Up to these times, the irradiated potatoes did not lose much weight, and the incidence of black rot was low. After these times, considerable loss in weight, softening and incidence of black rot was evident.

To report on the project more generally, I should like to break down each of the elements in the Radiation Processing as follows:

RAW MATERIAL

Products

1. Animal

   a. Red Meats
      (1) Beef
      (2) Pork

   b. Poultry

   c. Fish

2. Plant

   a. Fruit
   b. Vegetable
   c. Grain Products

1. The Project emphasis is in the order listed above.

2. There are two major potentials - pasteurized and sterilized products.

3. The interest of the Armed Forces is greatest in sterilized animal products.

4. The variables that must be studied are almost the same as those for fresh or for other types of processed products. The influence of all of these

variables on successful radiation processing is not yet known.

For example: Variables that must be studied in meats are; animal age, genetic history, previous diet, grade, aging, and cuts of meat used.

For plants they are; variety, area in which grown, maturity, post-harvest holding and treatment, use of product, etc.

FOOD PROCESSING

Variables in material preparation and processing again approximate those encountered in most other methods of processing products. In general these are:

a. Meat - slaughtering conditions, cooling period, holding time, etc.
b. Plant - washing, peeling, cutting, etc.

Determination of the radio-stability of enzymes in food products caused a major re-orientation in the approach to processing as it was realized that an enzyme inactivating step would be required for radiation sterilized foods.

Heat-enzyme inactivation is the only practical method presently known for food products and is practiced extensively in the frozen food industry. Requirements for heat-enzyme inactivation mean that only pre-heated or blanched products are possible at this time.

Some of the variables in product preparation that must be studied are - type of heat for enzyme inactivation, inactivating temperature used, curing, seasonings, additives, gravies, thickening agents, broth, etc.

For sterilized animal products, the reduction of oxygen content has been shown to markedly reduce the incidences of organic peroxide formation and development of irradiation odor/flavors, as well as reduce vitamin destruction. The complete absence of O_2 before and after irradiation appears to be most desirable.

Studies using oxygen scavenger to remove the residual oxygen left by vacuum or inert gas packing are now in progress.

PACKAGING

The packaging of irradiated foods presents some unique problems. While the cylindrical can can be used, a rectangular can would be much better from the irradiation treatment standpoint. Also, from a logistic point of view, a flexible plastic package would show great weight and volume advantage.

52249 O—60—pt. 1——21

RIGID CONTAINERS

Commercial end-sealing compounds (with the exception of those laminated with butyl rubber) are toughened and improved by irradiation. Interior enamels used in cans have been found to be satisfactory.

The design of the radiation source has an important bearing on the shape of the container to be used to obtain optimum dose distribution and energy utilization. Recent indications are that one or a number of parallel cobalt-60 plaques may be used in the gamma source at the U. S. Army Ionizing Radiation Center. With such a source design, the ideal shape of the container for gamma radiation would be rectangular; further, the rectangular shape is ideal for beta radiation since the beam scans the surface of the container and uniform thickness would give better dose distribution.

The tin-plate can commercially available has been found to be satisfactory. A study is in progress to determine the suitability of flat aluminum cans for irradiated foods. This aspect of the work is quite important, considering that certain rations require individual servings of food, a thin flat aluminum can would be eminently suited to this application. In addition, thin flat aluminum cans (one inch thick) could be irradiated with a 4-6 mev electron source. If this container should prove feasible, it would enable industry to package and irradiate such items with a relatively low capital outlay.

FLEXIBLE CONTAINERS

Composite plastic and plastic packaging are being evaluated because of their potential in saving weight and cubage. An objectionable feature has been the development of odors in some plastics during irradiation such as polyethylene and saran. In addition, failures due to stress-cracking have been observed and will need to be overcome.

Before flexible containers can be introduced into the supply system they must be capable of resisting the abuses they will encounter in shipment. The ability of the packages to resist abuse will depend upon the interior packing and the design of the shipping container. This has a bearing on the design of the equipment to carry out the irradiation since it would be desirable to irradiate within the shipping container, thereby minimizing handling and packing operations after the irradiation process. Based on work to date, the ideal shipping container from the rough handling viewpoint is too thick for the radiation process, whereas the ideal shipping container from the irradiation standpoint is too weak to withstand rough handling. Currently, it appears that the individual packages, either cans or flexible, would best be assembled in modules for irradiation, then, three or four modules assembled in the shipping container after irradiation.

It has been determined that at doses of one million rads or less, radiation has no significant effect on the physical characteristics of plastic film packages but some materials are slightly affected at levels of 2 million rads. However, even at a dose of 6 million rads the physical properties of Mylar, polyethylene, vinyl, polystyrene, and nylon are unaffected.

Films such as trifluoromonochlorethylene, saran, pliofilm, and celluloses show embrittlement above doses of 3 million rads and their usefulness for sterilized foods would, consequently, be limited.

A different problem in packaging is encountered when one considers radio-pasteurized fruits and vegetables. Packages of this type must provide for a transfer of sufficient amounts of oxygen to permit respiration of the perishable item. Improper packaging will markedly shorten the useful life of the item. On the other hand, the package must prevent recontamination of the item by microorganisms. Currently, silicone treated light dry waxed or oiled paper bags are fairly adequate, but improvements must be developed.

RADIATION PROCESSING

The dose required to obtain sterilization is a microbiological problem. "Sterilizing" dose for non-acid foods is presently established at 4.6 megarad. This sterilization dose is currently established as 12D, with a D value defined as the amount of radiation required to reduce the viable microbial population by a factor of 90 percent. In general, it appears that the D value, when radiation is used, is in the range of 400,000 rads.

Studies which led to the determination of this sterilizing dose established that not only were bacterial spores more resistant to radiation than vegetative cells but that considerable difference in radiation resistance existed between different species and within strains of a single species. Of primary interest is that the spores of the toxicogenic anaerobe Clostridium botulinum are the most radiation-resistant of those tested to date. In thermal processing Cl. botulinum is less resistant to heat than certain non-toxic spoilage organisms, while in processing by irradiation the reverse is true.

Certain high-resistant non-spore forming organisms have been found but they are not of food spoilage significance. Attempts are being made to characterize the cultural characteristics of these.

Inoculated pack studies are being used to define the "sterilizing" dose. This involves the seeding of food products with known numbers of Cl. botulinum spores and exposing the food to various levels of irradiation.

In 1954 research began with small 1- or 2-kilocurie cobalt sources available at universities. In addition to these, by August 1954, the Project had access to services from a 1-mev resonant transformer and a 2-mev Van De Graaff accelerator.

The source at Argonne National Laboratory was then non-existent. Dugway Proving Grounds had a small amount of radioactive tantalum in use but this was of little value to this Project. With the spur of the food irradiation needs, the spent fuel rod source at Argonne was made ready for operation in the first quarter of 1955, and the Dugway spent fuel rod source was developed shortly after that. Not until mid-1956 was the Dugway cobalt source ready for use.

In 1954 about 2 tons of food were irradiated for research under this Project. With the present expanded needs, the total irradiation for 1959 will approximate 200 tons of food.

During the last year additional electron sources with capabilities of 2-10 mev have been added. In July 1958, another milestone was reached with the addition of the new large capacity gamma source at the Savannah River Plant of the Atomic Energy Commission. This source was specifically created as a food irradiation facility for the Quartermaster Corps' effort.

The Food Radiation Preservation Division now has access to sources capable of irradiating any amount of food than can reasonably be required for research and development until the U. S. Army Ionizing Radiation Center begins to function.

The distribution of radiation dose within a can and between cans is a significant factor in quality control. Optimum distribution from a food quality standpoint would, of course, be absolute uniformity; however, this cannot be achieved.

The problem of dose variation in a number 10 can was approached both theoretically and experimentally. Theoretical calculations indicated about 5 percent dose variation in such a can exposed to a uniform field of 1-mev gammas. Results of an experiment conducted at Dugway Proving Ground with cans containing cobalt glass dosimeters in agar gel showed a variation of about 10 percent. Extensive measurements have been made to determine dose distribution in many types of containers and in all types of sources. These studies have pointed out that a dose distribution of between 100 percent and 125 percent is obtainable provided that the proper sizes of container are selected for the particular source.

A word is in order about induced radioactivity. Very early in the plans for the USAIRC, it was determined that a 24-mev electron source would be employed to irradiate containers of approximately 6 inches in thickness. The possibility of some induced radioactivity in containers and products was realized and a program was instituted to determine what these activities might be. A series of investigations have both experimentally and theoretically determined that induced activities from 24-mev electrons at doses higher than 5 million rads are measurable but of very low values. The significance of these values has not been resolved at this time.

The dosimetry problems faced at the initiation of this Project were indeed complex. Coupled with the large tonnage of food required was a multiplicity of contractors and sites, and the varied conditions of irradiation as dictated by experimental design and source capabilities. There was an extreme range of dose requirements from low level pasteurization requirements to doses of the order of 5 million or more rads. Methods used for routine dosimetry varied widely, as did densities of the food and container materials to be irradiated. The capabilities of the source had to be measured and the dose received by the product had to be measured accurately.

The dosimetry requirements were divided into three areas: a) primary standard dosimeter, b) operating standard dosimeter, and c) production control devices. It was decided that a calorimeter of some kind would be used as the standard. The National Bureau of Standards assumed responsibility for the development of this type of dosimeter.

In the fall of 1956, a contract was let to expedite work on the operating standard. One hundred or more systems were evaluated and in December 1957, cobalt glass and ceric sulfate dosimeters were selected as operating standards. By the use of these systems, dose delivered by any source can now be measured with accuracy.

A number of production control devices (go-no-go and beam monitors) are now under development. Some are usable but still require refinement. A recent development regarding the polymerization of styrene by radiation looks encouraging as a dosimeter. Systems of positive control are being designed to determine that each can or package has received the full dose.

FINISHED PRODUCT

Eight irradiated foods, six sterilized and two pasteurized foods have been fed to volunteer troops at Fort Lee, Virginia. At the time of the tests, the troops were not told which foods had been irradiated or whether they were eating the irradiated or non-irradiated items. While the official results have not been announced, an informal evaluation indicated that with the exception of one item, the irradiated items were as acceptable as their unirradiated counterparts. This is noteworthy particularly when one considers that all of the irradiated sterile foods had received at least 3 months storage at 72° F. while the controls were prepared from fresh products.

There is some weight of evidence now accumulating in the Project on the problem of irradiation flavor in beef which indicates that the irradiation introduces a new flavor, but that the consumer who is not familiar with the product does not discriminate against it. For example, beef steaks evaluated for intensity of radiation flavor were scored by "experts" as having varying degrees of irradiation flavor, but a "consumers" panel did not discriminate between samples and scored them as being very acceptable. Similar results occurred in the homogeneous beef study with 10 cooperating contractors who used standardized test procedures and a common sample of beef. Trained people could easily distinguish the "radiation flavor" (samples irradiated 0, 1.25, 2.5 and 5 megarad), but the uninitiated did not differentiate between the samples.

It is realized that more evidence on this point must be obtained, and that the further question of "recognition" must be explored. Also, it must be determined if repeated consumption of irradiated items will produce a change in attitude toward them. Off-flavor is not a major problem with pork or poultry, although the pink color, which gives the appearance of under-cooked meat, is definitely a problem with pork and to some extent in poultry.

In pasteurization the radiation dose usually is not sufficient to change the flavor or quality of the product, but it has been shown to markedly extend the storage life. It is expected that the very great potential in this area for increasing the marketable life of plant and animal products will be actively pursued and brought to function by industry, particularly when such foods are cleared in the wholesomeness program.

It is known that the vitamin content of irradiated products is reduced, much the same as occurs with thermally-processed products. Studies to determine the vitamin content of prototype irradiated meat samples are being initiated, and tables of nutrition values will be prepared much as for thermally-processed foods.

The storage stability of irradiated items is not yet well established with most products, primarily because insufficient time has elapsed since their production. Sterilized pork loin has been well-accepted both hot and cold after 16 months storage at 72° F. and chicken after storage for 12 months at 72° F. was very well liked. There seems reason to believe that an extended storage life will be possible.

The softening induced in plant products by irradiation combined with the necessity for heat-enzyme-inactivation indicates that great progress must be shown in overcoming this defect before irradiation-sterilized plant products will be sufficiently improved over their well-accepted thermally-processed counterparts to be important to the Armed Forces.

In discussing the radiation program and the progress being made, I have tried to outline the approach in establishing radiation processing as a substantial program, to describe the fundamental research seeking to determine what chemical and physical changes in foods are being produced by irradiation, especially as they affect food quality, nutrition or wholesomeness, and to tell you of the type of progress that is being made.

There are many problems ahead. While the program is now entering a phase of product development, the area of research must still be progressed to furnish material with which to solve some of the development problems. Thus, it is evident that the entire program must progress on a solid front in order to bring ration items into the food supply system of the Armed Forces. Remember that all assembled at this meeting are playing their part in this program and that the effort of every one is essential to success.

AD_____ Accession No. _____
QM Food & Container Institute for the Armed Forces, QM R & E Command, Chicago, QMF & CI Rpt. No. 4-59
Project No. 7-84-01-002 66 pages
Title: Proceedings, Contractors' Sixth Annual Meeting, Quartermaster Corps' Radiation Preservation of Foods Project

This report of the meeting, held 27-29 January 1959, at Highland Park, Illinois, summarizes technical discussions and speeches presented at the meeting.

Primary Field: Radiation Preservation of Foods
Secondary Field(s):

UNCLASSIFIED

AD_____ Accession No. _____
QM Food & Container Institute for the Armed Forces, QM R & E Command, Chicago QMF & CI Rpt. No. 4-59
Project No. 7-84-01-002 66 pages
Title: Proceedings, Contractors' Sixth Annual Meeting, Quartermaster Corps' Radiation Preservation of Foods Project

This report of the meeting held 27-29 January 1959, at Highland Park, Illinois, summarizes technical discussions and speeches presented at the meeting.

Primary Field: Radiation Preservation of Foods
Secondary Field(s):

UNCLASSIFIED

AD_____ Accession No. _____
QM Food & Container Institute for the Armed Forces, QM R & E Command, Chicago QMF & CI Rpt. No. 4-59
Project No. 7-84-01-002 66 pages
Title: Proceedings, Contractors' Sixth Annual Meeting, Quartermaster Corps' Radiation Preservation of Foods Project

This report of the meeting, held 27-29 January 1959, at Highland Park, Illinois, summarizes technical discussions and speeches presented at the meeting.

Primary Field: Radiation Preservation of Foods
Secondary Field(s):

UNCLASSIFIED

AD_____ Accession No. _____
QM Food & Container Institute for the Armed Forces, QM R & E Command, Chicago QMF & CI Rpt. No. 4-59
Project No. 7-84-01-002 66 pages
Title: Proceedings, Contractors' Sixth Annual Meeting, Quartermaster Corps' Radiation Preservation of Foods Project

This report of the meeting, held 27-29 January 1959, at Highland Park, Illinois, summarizes technical discussions and speeches presented at the meeting.

Primary Field: Radiation Preservation of Foods
Secondary Field(s):

UNCLASSIFIED

Department of the Army
Office of The Surgeon General

Contract No. DA-49-007-MD-544

ON THE NUTRITIVE VALUE OF THE MAJOR NUTRIENTS OF IRRADIATED FOODS

and

APPRAISAL OF THE TOXICITY OF IRRADIATED FOODS

V. Chalam Metta
M. S. Mameesh
B. Connor Johnson

Division of Animal Nutrition
University of Illinois
Urbana

Progress Report No. 15
for period
September 21, 1958 - March 15, 1959

This is not a final report. Conclusions stated are subject to change on the basis of additional evidence. Information contained herein is not to be reprinted or published without written permission from Research and Development Division, Office of The Surgeon General, Department of the Army, Washington 25, D. C.

Summary

We have demonstrated that the rat does require dietary vitamin K on certain diets, including irradiated beef diets. Vitamin K deficiency (hemorrhagic syndrome) can be produced in rats if the diet is very low in vitamin K and if coprophagy is prevented. Irradiation of beef results in the destruction of vitamin K and production of new compounds, such as the carbonyls; the latter appear to render the feces unacceptable to the rat and thereby coprophagy is reduced.

Carbonyls do not seem to interfere with the absorption of dietary fat-soluble vitamin K.

Carbonyl compounds such as are produced in beef due to irradiation have no metabolic anti-vitamin K effect. This conclusion is based on a study of plasma prothrombin times as affected by injections of carbonyls and steam distillates of irradiated beef extract.

Prolonged prothrombin times and hemorrhages resulting in rats due to carbonyl ingestion can be effectively prevented by vitamin K supplementation.

Not only the solvent extract of the irradiated beef but also its residue causes hemorrhage. In either case, vitamin K supplementation can protect the rat.

If mixed with irradiated beef vitamin K seems to be destroyed or inactivated by some component of the irradiated beef. Two of 8 male rats fed (5.6×10^6 rad) irradiated beef diet to which 2.5 µg of vitamin K_3 per gm of diet was added during mixing, died from hemorrhage. This diet contained adequate amounts of essential fatty acids and vitamin E besides other nutrients required for the rat.

Uncooked irradiated beef, like the autoclaved irradiated beef, produces vitamin K deficiency in the male rat.

Methionine or lard supplementation of the (vitamin K-free) irradiated beef diets does not protect the rat from the hemorrhagic condition.

We have developed a vitamin K-low synthetic diet which produces vitamin K deficiency in the rat in about 10 days. By preventing coprophagy we can produce the hemorrhagic diathesis in about 5 days.

In our progress report No. 14 we have postulated the following reasons for the hemorrhagic syndrome encountered with irradiated beef diets in the rat: (1) Irradiation at the level of 3×10^6 r or more destroyed the vitamin K activity in beef; (2) Irradiation of the beef at 6×10^6 r rendered the feces produced from diets that contain it unacceptable to the rat, and thus vitamin K was not obtained by the rat from the feces; (3) On irradiated beef diets the rat could not depend on coprophagy alone to supply its physiological needs of vitamin K even though on 3×10^6 r irradiated beef he consumed 20-30% of his feces.

Vitamin K Deficiency or Vitamin K Antagonist?

Although our studies on the hemorrhagic syndrome so far showed no indication that an antagonist(s) to vitamin K was produced in beef by irradiation, an experiment was specifically set up to test this possibility. The basis for this experiment was that if irradiated beef contained a vitamin K antagonist or some other hypoprothrombinemic factor, the severity of the hemorrhagic syndrome should increase as the level of irradiated beef in the diet was raised. Three diets were mixed as shown in table 1. The diets contained, by calculation, the same caloric, protein and fat content on a dry matter basis. Drackett assay protein and corn oil were used to make up the differences in protein and fat, respectively. The diets contained 42.0, 21.0, and 10.5 percent of beef (solids) irradiated at 3×10^6 r. The results of this experiment are shown in table 2. It is obvious from this table that the severity of the hemorrhagic syndrome increased as the level of irradiated beef in the diet was decreased. This indicates that the irradiated beef was not contributing vitamin K antagonists, but rather that irradiated beef was very low in vitamin K content. Drackett protein, according to this experiment, contained less vitamin K than irradiated beef.

Irradiated beef has been shown to contain higher levels of aldehydes than control beef (Schweigert; Monty). Experiments in this laboratory have shown that addition of 0.5% n-decylaldehyde to non-irradiated beef or casein diets known to be marginal in vitamin K precipitated hemorrhages in rats fed those diets. It was not known whether the aldehydes produced this effect by acting in the intestines, i.e., by decreasing absorption of microbially synthesized vitamin K, by reducing coprophagy, or by acting as metabolic antagonists to vitamin K. Experiments were therefore conducted to find out whether aldehydes would produce their hemorrhagic effect when injected. When subcutaneous or intraperitoneal injections were undertaken, no hemorrhages were induced, but it was questioned whether sufficient absorption occurred to warrant conclusions. So it was decided to inject aldehydes intracardially. N-decylaldehyde, n-octadecylaldehyde and the steam distillate of 6 million r irradiated beef fat were used. Appropriate amounts of each were suspended in warm Krebs-Ringer's buffer by means of a small quantity of Tween 80 and injected intracardially into rats which had been fed control beef diet for several weeks in order to deplete the vitamin K stores. Twelve hours following injection, the rats were sacrificed and plasma prothrombin times were

determined. From table 3 it can be seen that none of the aldehydes tested or the steam distilled fraction of irradiated beef fat had any effect on the prothrombin times. The results of this experiment support the conclusion that aldehydes had no metabolic anti-vitamin K effect and that their action probably occurs in the gastro-intestinal tract by contributing to the unacceptability of the feces, i.e., by reducing coprophagy.

Absorption of Dietary Vitamin K

It is possible that the severe vitamin K-deficiency (hemorrhagic syndrome) observed in rats fed irradiated beef was partly due to interference with the absorption of the naturally occurring (fat-soluble) forms of vitamin K in the diet. This interference could conceivably be caused by compounds such as aldehydes which are produced in beef by ionizing radiation. An experiment was therefore set up to investigate if the absorption of fat-soluble vitamin K was blocked in rats fed irradiated beef. It is agreed as a basis for this experiment that absorption of water-soluble vitamin K involves a separate mechanism from that of the fat-soluble forms. For example, the absorption of the former does not depend on bile, while the latter does. If, therefore, absorption of fat-soluble vitamin K was blocked in rats fed irradiated beef, its potency in protecting the rats from hypoprothrombinemia would be much lower than that of the water-soluble form of the vitamin on equimolar basis. The results of this experiment are shown in table 4. It can be seen that the potencies of the water- and fat-soluble forms of vitamin K were equivalent. This indicates that the absorption of the naturally occurring fat-soluble vitamin K was not specifically blocked in rats fed irradiated beef. It should be noted here, however, that this conclusion applies to the vitamin K supplied in the diet and does not rule out an effect on the absorption of vitamin K synthesized by intestinal bacteria.

Production of Hemorrhagic Syndrome on a Purified Diet

It has usually been assumed that the rat requires no dietary supply of vitamin K and that its physiological needs of this vitamin were adequately supplied by the intestinal microflora. This was the reason why in our original long-term experiment no vitamin K was added in the diet, and this was also the reason for the concern over the hemorrhagic syndrome observed with irradiated beef.

A purified diet containing 20% drackett assay protein and 66% sucrose was formulated as shown in table 5. In order to examine the effect of aldehydes on the production of vitamin K-deficiency in rats fed a purified diet, n-decylaldehyde at a level of 0.2% of the drackett diet was used. 5 /ug of menadione diphosphate ester per rat per day were orally administered to a group of rats fed the basal drackett protein diet and to another group of rats receiving the same diet containing the aldehyde. Two groups of rats were prevented from practicing coprophagy by means of tail cups; both groups received the drackett protein diet. One of these groups received 5 /ug menad

diphosphate ester per rat per day; and the third group served as control. The period of the experiment was 10 days. Coprophagy was calculated in all groups on the 7th and 8th day. Whole plasma prothrombin times were determined on all rats on the 10th day of the experiment.

The results are given in table 6. It can be seen from the table that deaths from hemorrhage occurred in all groups fed the drackett protein diet without oral vitamin K supplement. The coprophagy-prevented group suffered the greatest number of fatal hemorrhages. No deaths occurred in the animals supplemented with 5 /ug menadione per day. All the rats fed the control diet survived whether aldehyde was included or not. The data on prothrombin time confirm the finding that the rats fed the drackett protein diet and prevented from coprophagy suffered the greatest shortage of vitamin K. This indicates that on this diet the rat derives a substantial part of its vitamin K supply by consuming its feces. N-decylaldehyde slightly prolonged the prothrombin time and reduced coprophagy. This indicates that the aldehyde was probably rendering the feces unacceptable to the rat and therefore reducing the vitamin K supply of the rat which is usually obtained by coprophagy. In all cases, however, 5 /ug of vitamin K supplied orally each day restored the prothrombin times to normal and completely prevented hemorrhages.

These results indicate that the rat does indeed require a dietary supply of vitamin K, at least with certain diets. Coprophagy appears to be a source of supply of vitamin K for the rat, and where the diet is free or very low in vitamin K, coprophagy assumes greater importance as a supply source of the vitamin.

Carbonyl Compounds & Vitamin K Relationship

Since some processing methods, particularly the ionizing radiations, are known to produce carbonyl compounds in foods, the effect of feeding carbonyl compounds to the growing rat has been investigated. We have already reported that carbonyl compounds when included in non-irradiated beef diets or synthetic diets cause fatal hemorrhages in the rat. Autopsy revealed sub-cutaneous bleeding, hemothorax, bloody epididymis, etc. No vitamin K was added to any of the diets.

Vitamin K Protection of Carbonyl-fed Rats

Since the autopsy symptoms on rats fed carbonyls are reminiscent of vitamin K deficiency, an experiment was undertaken to test if vitamin K will counteract the metabolic disturbances caused due to carbonyl ingestion. Decanal was the carbonyl chosen. The basic composition of the diets was beef (irradiated or non-irradiated) 35% (this is equivalent to 88 gm. wet beef, in which form it was mixed in the diet), starch 35%, sucrose 19%, cod-liver oil 1.5%, wheat-germ oil 0.5%, mineral mixture 4%, and vitaminized cerelose 5%. The vitamin mix provided thiamine HCl, 10 /ug; riboflavin, 10 /ug; calcium pantothenate, 50 /ug; nicotinic acid, 20 /ug; pyridoxine, 5 /ug; folic acid, 1 /ug; vitamin B_{12}, .05 /ug; biotin, .01 /ug; and choline chloride, 1 mg. per gram of (dry) diet. The plan and results of the experiment are given in table 7. The duration of the experiment was 62 days.

Prothrombin times were considerably longer (approximately 44 seconds) in rats fed carbonyls. In addition, carbonyl feeding resulted in fatal hemorrhages. However, vitamin K supplementation restored the prothrombin times to normal (approximately 16 seconds). No hemorrhages were observed in decanal-consuming rats supplemented with vitamin K. The data clearly demonstrate that vitamin K can effectively protect the rat consuming carbonyl compounds. Thus, there seems to be some type of antagonism between long-chain aldehydes and vitamin K in the case of the rat.

Effect of Decanal Injections

After demonstrating that vitamin K will restore the prothrombin times and prevent fatal hemorrhages in rats consuming carbonyls, we wanted to study the mechanism of action of carbonyls. For this purpose, we injected decanal subcutaneously, intraperitoneally, and intracardially into healthy growing rats receiving non-processed beef diets. The vehicle used was corn oil. The experimental data are summarized in table 8.

Subcutaneous injections of decanal (in 0.4 ml. corn oil vehicle) for 10 days did not result in hemorrhages. However, abrasive pockets were prominent at the site of injection below the skin; in some cases blue patches were also observed. Obviously, decanal was not being absorbed by the tissue fluids when injected below the skin.

When 250 mg. of decanal in corn oil was injected intraperitoneally, 1 of 3 rats died from toxicity, not from hemorrhage. There was significant swelling of the abdomen in all three rats. On opening the abdomen a large amount of exudate was noticed.

Intracardial injection with decanal in corn oil resulted in the death of the animal within 24-48 hours. (The technique of cardiac puncture was presumably good since the control animals survived.) There were no hemorrhages in the rats.

The results of this experiment, therefore, indicate that, whatever the compounds that are resulting in beef due to ionizing radiations, they are not vitamin K antagonists. The rats come down with K deficiency only when the carbonyls are ingested by the rat and not when they are injected into the animal's metabolic pool. Thus, the effect of carbonyl ingestion on the well-being of the rat is an indirect one.

We have also noted that it takes a considerably longer time (8 weeks) to produce the vitamin K deficiency syndrome by feeding the n-decylaldehyde, whereas on irradiated beef diet the rats come down with deficiency in about 4 weeks. Furthermore, the deficiency caused by decanal feeding is not as severe as it is by irradiated beef feeding. Perhaps there may be some other irradiation-induced compounds also in beef which cause the hemorrhagic diathesis in the male rat.

Methionine & Lard Supplementation: The Hemorrhagic Syndrome

Sulfur amino acids as well as some essential fatty acids have been shown to be very sensitive to ionizing radiations. In view of the implication of the sulfhydryl groups in the respiratory enzyme systems, we investigated the effect of methionine supplementation of the irradiated beef diets. Another group was supplemented with stripped lard (which is presumably free from fat-soluble vitamins). (Our original vitamin K-free diets which contain 35% (solid) irradiated beef, 1 1/2% cod-liver oil, and 1/2% wheat-germ oil, etc. was used). The growing male rats were fed ad libitum for 44 days. The results of the experiment are given in table 9.

Methionine supplementation did not alleviate the harmful nature of the irradiated beef for the rat. There were 7 deaths in this group; deaths of these rats occurred on the 15th, 19th, 24th, 25th, 30th, 33rd, and 34th day of feeding, respectively.

Supplementation with stripped lard also did not offer any protection. Four of ten rats died from hemorrhage. The deaths of these rats occurred on the 21st, 25th, 29th, and 33rd day of feeding, respectively.

Effect of Feeding Vitamin K-containing Irradiated Beef Diets to Growing Male Rats

Our data have already shown that female rats consuming irradiated beef do not succumb with vitamin K deficiency, whereas the male rats do. Further, the lactation-reproduction performance of female rats consuming irradiated beef diets is quite satisfactory. However, these diets did contain 1 microgram of vitamin K_3 per gram of the diet, which was added to the diet during mixing. These diets were mixed and stored frozen for 4-8 weeks. It is possible that some of the added vitamin K_3 might have been inactivated or destroyed due to mixing with the irradiated beef (which has a high peroxide number and other radiation-induced products). The resistance of the female rat to vitamin K deficiency, under our experimental conditions which have proved so harmful to the male rat, may be due to a low vitamin K requirement for the female rodent. The female sex hormones may be breaking down into vitamin K-active compounds under normal or stress metabolic conditions. It is possible, also, that female rats get their intestinally synthesized vitamin K by direct absorption and, more so, by coprophagy (the coprophagy habits of female rats eating irradiated beef is presently being studied).

In order to test the destruction of vitamin K due to mixing with irradiated beef, a 78-day feeding experiment was undertaken on weanling male rats. The percentage composition of the test diets was as follows: beef (control or 2.8 megarad or 5.6 megarad) 35 (87.5 gm. wet beef was used which corresponds to 35 gm. dry solids); flour, 35; casein, 5; wheat-germ oil, 6; mineral mixture 446, 4; amidex, 10; and vitaminized cerelose, 5. The vitaminized cerelose is similar to the one we have reported before except that it

now provides in addition 2.5 micrograms of vitamin K_3 per gram of the diet. The diets were mixed to last for 4 weeks at a time, and stored frozen. Rats were orally administered 1000 units of A, 100 units of D, and 15 mg. α-tocopherol acetate once a week.

The mortality data in this experiment are as follows:

Diet ingredients	No. of male rats	Deaths from hemorrhage
$Beef_0$, $Flour_0$	5	0
$Beef_{2.8}$ megarad, Flour 37,200 rad	8	0
$Beef_{5.6}$ megarad, Flour 74,400 rad	8	2

Two of eight growing rats consuming 5.6 megarad irradiated beef died from hemorrhage. The first death on this diet was observed on the 46th day of feeding. The test diets contained 6% wheat-germ oil, which is rich in unsaturated fatty acids as well as in vitamin E, and possibly some vitamin K. In addition, the test animals were given orally adequate amounts of vitamins A, D, and E, once a week. Thus, there was more than adequate intake of essential fatty acids and vitamin E. The deaths due to eating of irradiated beef, therefore, can hardly be due to deficiency of essential fatty acids or vitamin E. Vitamin K_3 was, of course, mixed in the diets but not given orally. 2.5 micrograms of K_3 per gram of the diet is certainly a heavy dose in the rat's diet.

The data of the experiment, thus, indicate that if vitamin K_3 is mixed in the diet with the irradiated beef, the male rats succumb with vitamin K deficiency. Irradiation-induced products in beef (for example, active oxygen, organic peroxides, free radicals, carbonyls, etc.) seem to destroy, directly or indirectly, the vitamin K mixed with the irradiated beef.

Effect of Feeding Uncooked Irradiated Beef

In all our feeding experiments to appraise the toxicity of irradiated beef we have been cooking beef in an autoclave for 25 minutes at 15 lbs. pressure before incorporating the beef into test diets. We have repeatedly demonstrated that growing male rats come down with fatal hemorrhages when they consume these diets. In order to test the possibility that autoclaving is partly responsible for the harmful effects of irradiated beef, a feeding experiment was undertaken using non-cooked irradiated beef. A diet of the following composition was mixed: non-cooked irradiated (2.8 megarad) beef, 35% (solids); flour, 35%; sucrose, 19%; K-free vitaminized cerelose, 5%; wheat-germ oil, 1/2%; cod-liver oil, 1 1/2%; and minerals, 4%. When this diet was fed ad libitum to growing male rats, 2 of 6 rats died from hemorrhage within 12 days of feeding the diet. Plasma prothrombin times on 4 rats gave values

of 56, 27, 75, and 66 seconds, respectively. Thus, the data of the experiment show that autoclaving of the irradiated beef is not aggravating the harmful effects of irradiated beef, but it is irradiation per se which results in vitamin K deficiency in the male, under our experimental conditions.

Fractionation of Irradiated Beef

In our report 14 we reported that the toxic compounds (presumably the carbonyls) are found predominantly in the ether extract of the irradiated beef. Following a similar procedure for fractionating beef (see report 14), we conducted one more feeding experiment to confirm our observations.

Four diets were formulated according to a factorial design. The basic composition of the reconstituted diets except for the beef component was similar to what we have reported in table 7 of report 14. Vitamin K was not included in any of the diets. Diet 1 (control) contained non-irradiated beef residue and non-irradiated beef extract; diet 2, irradiated beef residue and non-irradiated beef extract; diet 3, non-irradiated beef residue and irradiated beef fat; diet 4, irradiated beef residue and irradiated beef fat.

Four groups of weanling male rats (10 rats on diet 1, 20 rats each on diets 2, 3, & 4) were fed individually these diets, ad libitum. Half of the rats in groups 2, 3, & 4 (which were receiving irradiated beef residue or extract or both) were given daily 10 /ugm of water-soluble vitamin K orally. The experiment lasted for 30 days. The results of the experiment are given in table 10.

The data reveal that the beef residue as well as the solvent extract of the irradiated beef prepared under our experimental conditions is harmful to the male rat. Five rats on irradiated beef residue, three rats on solvent extract of irradiated beef, and seven rats on the residue plus the solvent extract of the irradiated beef died from hemorrhage. These data extend our previous observation, namely, that the toxic compounds (presumably the carbonyls) are not only present in the solvent extract but also in the residue of the irradiated beef.

Oral supplementation with vitamin K is able to protect the rat consuming the residue, the solvent-extract, or both of these components, of the irradiated beef.

Our procedure for fractionation of irradiated beef consisted in drying the beef for 2-3 days by blowing hot air. The dried beef was then extracted with ethyl ether in a Soxlet apparatus for 48 hours. The ether was distilled off under reduced pressure, and the beef residue was air-dried, ground and redried for 2 days at 120° F. Thus, the conditions under which irradiated beef was dried and extracted could very well oxidize the aldehydes. However, we are able to produce the hemorrhages by feeding beef fractions. Perhaps the aldehydes are firmly bound to the protein or lipid components in some manner.

Jo-10

52249 O—60—pt. 1——22

Papers Published

Johnson, B. Connor, V. C. Metta, and W. S. Tsien. The effect of irradiation sterilization on the nutritive value of the protein and energy components of foods. Second United Nations International Conference on the Peaceful Uses of Atomic Energy, September 1-14, 1958. Journal No. 12, p. 7. (title only)

Metta, V. C. and B. Connor Johnson. Biological value of gamma irradiated corn protein and wheat gluten. J. Agr. Food Chem. 7, 131-133, 1959.

Metta, V. C., M. S. Mameesh, and B. Connor Johnson. Vitamin K deficiency in rats induced by the feeding of irradiated beef. J. Nutrition, in press.

Metta, V. C., M. S. Mameesh and B. Connor Johnson. Fat carbonyls and vitamin K deficiency. Am. Chem. Soc. Abstracts, Boston, Mass., April, 1959, in press.

Metta, V. C., M. S. Mameesh, and B. Connor Johnson. Irradiated beef and the hemorrhagic syndrome. Fed. Proc., 1959, in press.

Tsien, W. S. and B. Connor Johnson. The effect of radiation on the nutritive value of foods. IV. On the amino acid composition of garden peas and lima beans. J. Nutrition, in press.

Tsien, W. S. and B. Connor Johnson. The effect of radiation sterilization on the nutritive value of foods. V. On the amino acid composition of milk. J. Nutrition, in press.

Personnel

Chief Investigator: Dr. B. Connor Johnson

Personnel working on the project during the period of this report:

Dr. V. Chalam Metta, Research Assistant Professor
Dr. M. S. Mameesh, Research Assistant
Dr. P. B. Rama Rao, Research Assistant
Mr. Louis Nash, Junior Laboratory Attendant
Mr. George Klain, (half-time) Research Assistant
Mr. James Gergan, (half-time) Junior Laboratory Attendant
Plus student help

VCM:MSM:BCJnjt
3/27/59

TABLE 1

Effect of increasing levels of irradiated beef; composition of diets

Ingredient	Diet A %	Diet B %	Diet C %
Beef, 3 x 10^6 r	42.0	21.0	10.5
Drackett Assay Protein	--	17.0	25.5
Mazola (corn) Oil	--	4.0	6.0
Sucrose	18.0	18.0	18.0
Starch	29.0	29.0	29.0
Cod-liver Oil	1.5	1.5	1.5
Wheat-germ Oil	0.5	0.5	0.5
Salts No. 446	4.0	4.0	4.0
Vitaminized Cerelose (minus K)	5.0	5.0	5.0
	100.0	100.0	100.0

TABLE 2

Effect of increasing levels of irradiated beef on hemorrhagic syndrome

Diet	No. of rats	Hemorrhagic Deaths			
		1st week	2nd week	3rd week	total
A(42% B 3 x 10^6 r)	8	0	0	2	2
B(21% B 3 x 10^6 r)	8	0	0	6	6
C(10.5% B 3 x 10^6 r)	8	1	3	2	6

TABLE 3

Effect of intracardially administered aldehydes

Diet	Dose	Prothrombin time (seconds)
Control beef	2 mg. Tween 80	17
"	1 mg. n-decylaldehyde + 2 mg. Tween 80	15
"	2.5 mg. n-decylaldehyde + 2 mg. Tween 80	15
"	1 mg. n-octadecylaldehyde + 2 mg. Tween 80	15
"	1 mg. B_6 fat steam-distillate + 2 mg. Tween 80	15

TABLE 4

Absorption of water- vs. fat-soluble menadione in rats fed irradiated beef

Diet	Oral Supplement per rat/day	Prothrombin time, seconds	Hemorrhagic deaths (%)
Beef, 3 x 10^6 r		24	25
"	1 /ug K_3 in H_2O	27	0
"	3 /ug K_3 in H_2O	16	0
"	6 /ug K_3 in H_2O	16	0
"	corn oil	23	0
"	1 /ug K_3 in corn oil	20	0
"	3 /ug K_3 in corn oil	15	0
"	6 /ug K_3 in corn oil	14	0

Jo-15

TABLE 5

Diet used to produce vitamin K-deficiency in the rat

Ingredient	%
Sucrose	66.5
Drackett Assay Protein	20.0
Dl. Methionine	0.5
Vitaminized Cerelose (without Vitamin K)	5.0
Salts No. 446	4.0
Wheat-germ Oil	0.5
Cod-liver Oil	1.5
Glycerol	2.0
Total	100.0

TABLE 6

Effect of coprophagy and decylaldehyde on vitamin K-deficiency in the rat

Diet	Oral supplement per rat per day	% death	Prothrombin time (second)	Coprophagy %
Drackett		17	32	38
"	5 /ug K_3	0	14	29
" + 0.2% Aldehyde*		17	44	18
" + 0.2% Aldehyde	5 /ug K_3	0	14	21
" Coprophagy prevented		67	92	--
" Coprophagy prevented	5 /ug K_3	0	15	--
Control Beef		0	13	21
" + 0.2% Aldehyde		0	19	14
" + 0.2% Aldehyde	5 /ug K_3	0	14	31

* - n-decylaldehyde

Jo-17

TABLE 7

Metabolic Relationship between n-decylaldehyde and vitamin K

Group	Beef Ingredient in diet	Decanal fed[1] orally	Vitamin K_3 [2] supply daily	No. of rats	Deaths
1	Beef (5.6×10^6 rad)	--	--	9	5
2	Beef (non-irradiated)	--	--	8	0
3	"	100 mg.	--	8	1
4	"	100 mg.	10 /ug	8	0
5	"	200 mg.	--	8	4
6	"	200 mg.	10 /ug	8	0

1. 100 or 200 mg. of n-decylaldehyde was mixed every day in the diet offered to the rat.

2. Fat-soluble vitamin K_3 was mixed fresh daily in the diet offered to the animal.

TABLE 8

Effect of carbonyl injections on male rats

No. of rats	Decanal per day in 4 ml. mazola mg.	No. of deaths
Subcutaneous Injections		
3	0	0
2	25	0
2	50	0
2	100	0
5	250	0
Intraperitoneal Injections		
3	250	1
Intracardial Injections		
2	0	0
2	50	2
2	100	2

TABLE 9

Methionine and lard supplementing effects on irradiated beef induced hemorrhages

No. of rats	Diet	Deaths from hemorrhage	Prothrombin time (seconds)
10	B 2.8 x 10^6 rad	3	21
10	" " + 10% lard[1]	4	25
10	" " + 0.5% dl-methionine	7	22

1. Lard was added at the expense of starch.

TABLE 10

Effect of feeding irradiated beef residue and solvent extract to growing male rats

Beef Component	Group	Vitamin K oral supplementation	No. of rats	Mortality
B_0 Residue B_0 Fat	1	No K	10	1
B_3 Residue B_0 Fat	2A	No K	10	5
" " " "	2B	K given	10	0
B_0 Residue B_3 Fat	3A	No K	10	3
" " " "	3B	K given	10	0
B_3 Residue B_3 Fat	4A	No K	10	7
" " " "	4B	K given	10	0

Jo-21

Progress Report No. 1

HEMORRHAGIC SYNDROME IN RATS FED IRRADIATED BEEF

By

E. A. Doisy, Jr., M.D.,
Associate Professor of
Internal Medicine

and

J. T. Matschiner, Ph.D.,
Instructor of Biochemistry

St. Louis University School
of Medicine, St. Louis 4,
Missouri

Contract No. DA-49-007-MD 996

Period: 1 September 1958 to 1 April 1959

THIS IS NOT A FINAL REPORT. CONCLUSIONS STATED ARE SUBJECT TO CHANGE ON THE BASIS OF ADDITIONAL EVIDENCE. INFORMATION CONTAINED HEREIN IS NOT TO BE REPRINTED OR PUBLISHED WITHOUT PERMISSION FROM RESEARCH AND DEVELOPMENT DIVISION, OFFICE OF THE SURGEON GENERAL, DEPARTMENT OF THE ARMY, WASHINGTON 25, D. C.

INTRODUCTION

In our contract with the Office of the Surgeon General, we proposed to assist in the elucidation of the Hemorrhagic Diathesis which occurs in rats fed purified rations containing 35% irradiated beef. Subsequent investigations depend on reproducing the syndrome described by the Urbana and Denver workers.

This report, then, deals with the results obtained in screening procedures to determine conditions optimal to the production of the diathesis.

METHODS

Essentially three diets have been fed, the compositions of which are shown in Table I. In addition to the Johnson-type diet, we were interested in ascertaining the effects of the diet designed by W. H. Griffith and used routinely at this institution. After receiving the letter circulated by Col. Cox concerning decanal (26 Aug., 1958, Cox/65472), we studied the effects of this compound added to the diets in use at St. Louis University (SLU) at levels suggested by Dr. Metta, Table I.

Animal sources were those of our own colony, maintained in pure line for at least 36 years, originally of the Wistar strain. As the first experiments unfolded, it became evident that our earlier experiences with Vitamin K deficiency in these rats were being duplicated: our strain is resistant to this avitaminosis. Consequently, we obtained a small breeding colony of the Sprague-Dawley strain from Madison, Wisc., and have begun feeding experiments with these animals. The results of these experiments will be included at a later date.

The lack of hemorrhage in these studies prompted study of a Dicumarol-sensitivity test to be used in rats after six or more weeks of experimental feeding. In essence, 2.5 mg. of Dicumarol was incorporated into 2 gm. of diet and fed after a 12 hour fast, to assure complete, rapid consumption (Overman, et al., J. Nutr., 23:589, 1942).

Twenty-four hours later blood was withdrawn by cardiac puncture (under light ether anesthesia) for determination of prothrombin time. 0.45 ml. of blood was collected into a 1 ml. tuberculin syringe fitted with a 21 gauge needle and containing 0.05 ml. of 3.8% sodium citrate. The contents of the syringe were mixed with 0.5 ml. of a citrate-saline mixture containing 5 parts of 0.9% NaCl and 1 part of 3.8% sodium citrate. After centrifugation in a clinical centrifuge for 10 min., the clotting time of the supernatant diluted plasma was determined in triplicate with Simplastin (Warner-Chilcott) using the procedure recommended by the manufacturer. The above dilutions are essentially those described by Biggs and Macfarlane (Human Blood Coagulation and Its Disorders, Thomas, Springfield, Ed. 2, 1957, p. 404), and yield prothrombin times of 16-18 seconds in normal rats.

Animals were housed individually in 1/2 inch wire mesh cages, and received food and water ad libitum. In some experiments, restraint was imposed by adjustable tubular cages of wire cloth, in an effort to prevent coprophagy, the importance of which has been shown by Barnes, et al. (Fed. Proc., 17, 470, 1958).

Diets were prepared as indicated in Table I and stored at -20°C; opened containers were refrigerated at 4°C for no longer than 10 days.

RESULTS

The results of a pilot experiment feeding SLU diet with and without Vitamin K_3 (2-methyl-1,4-naphthoquinone) to weanling male rats of the SLU strain are presented in Table II. Prevention of coprophagy by restraint led to depression of weight gain but was without influence on prothrombin time as shown in Table III. However, under the influence of a challenging dose of Dicumarol, a difference in the nutritional adequacy of the control and deficient diets became apparent.

Inclusion of 0.5% decanal into the SLU diet with and without menadione was without significant effect on weight gain, prothrombin time, or on the effects of a challenging dose of Dicumarol. The data are shown in Table IV.

The results of feeding the Johnson-type irradiated and control beef diet to SLU weanling rats are shown in Table V. Both B_0 and B_6 diets permitted significantly better weight gain than did purified diets. Although the effects of the B_6 diet were more marked, the lengthened prothrombin times indicate the hemorrhagenic properties of both diets. No evidence of hemorrhagic diathesis appeared until the 10th week of feeding when an animal on B_6 diet died of hemorrhage as the result of a minor cut on a digit of a front paw. However, on autopsy no evidence of internal hemorrhage was apparent. Two additional animals on the B_6 diet died similarly, again without evidence of internal hemorrhage during the 12th and 13th weeks of feeding, respectively.

Ten control animals and 22 animals fed the Johnson-B_6 diet were autopsied on sacrifice after 10 to 12 weeks. Only one animal displayed any internal bleeding -- a minor hemorrhage of the epididymis. The animal had been fed control diet, Johnson-type B_0.

A small series of rats was used to determine the effects of B_0 and B_6 beef diets containing salt and vitamin mixtures which have been used in our laboratory. These diets differ, as shown in Table I, from those used by Johnson only in micronutrients. The results were sufficiently different from those obtained with the Johnson-type diet to warrant inclusion in this report. As shown in Table VI, weight gain of both groups of rats was similar to those observed on the Johnson-type diet; however, prothrombin times after ten weeks were essentially normal. Severe hemorrhagic tendency in both groups was produced only after testing with Dicumarol.

DISCUSSION

At the Contractor's meeting in Highland Park, we reported verbally that we had seen no evidence of hemorrhage in any rats. Since that time three out of 46 animals on the Johnson-type B_6 diet have died of external hemorrhage after 10-13 weeks of feeding, and nearly all the animals examined after 13 weeks on both the B_0 and B_6 diet exhibited significantly prolonged prothrombin times. Nevertheless, the syndrome developed in our experiments is much less severe and delayed

in onset than that reported by other workers. Since this may represent a difference in rat strain, we have begun experiments with animals of the Sprague-Dawley strain. Evidence of such a strain difference in susceptibility to the beef diet was reported by Dr. Richardson in his letter dated 25 February, 1959.

Since in many of our experiments no evidence of deficiency was observed in weight gain, visible hemorrhage or by determination of prothrombin time by the one-stage method, response of the experimental animals to a challenging dose of Dicumarol has proved valuable. As seen in Table III and again in Table VI, inadequacy of the deficient diet could be detected with Dicumarol although no differences in weight, external appearance and one-stage prothrombin times had been observed. On this basis the inclusion of 0.5% decanal into the SLU purified diet deficient in Vitamin K does not affect its nutritional adequacy (see Table IV).

Comparison of the data in Tables III and IV suggests the remarkable effects of coprophagy on sensitivity to Dicumarol; it should be noted that one week following the hemorrhagenic drug, prothrombin times had returned to normal (Table III).

After completion of the present experiments with animals of the Sprague-Dawley strain, we plan to establish a standardized procedure to produce hemorrhage to facilitate further investigations into the mechanisms involved in irradiated beef diets.

ACKNOWLEDGMENTS

This is the first of a series of reports on Hemorrhagic Diathesis in rats fed diets containing fresh or irradiated beef. These investigations are sponsored jointly by the Offices of the Surgeon General and Quartermaster General, and St. Louis University.

The beef used in these diets was purchased by the Office of the Quartermaster General and gamma-irradiated at the Savannah River Plant, Ga.

The authors are indebted to Mr. V. A. Mahanger for his capable assistance and to members of the Staff of Biochemistry for their helpful advice and encouragement. We wish to thank Miss Corinne Dewes, in charge of our animal colony, for her unstinting efforts in our behalf.

Table I

DIET COMPOSITION

SLU: Purified Casein Diet

200	gm.	vitamin-free casein
588	"	powdered sucrose
80	"	lard
50	"	vitamin-B complex mixture
20	"	fat-soluble vitamin mixture
20	"	salt mixture 3A
20	"	salt mixture 3B
20	"	Ruffex (celluration)
2	"	L-cystine
1000	"	

This diet is essentially that designed by Dr. W. H. Griffith and reported by Doisy, Jr. and Bocklage (Proc. Soc. Exp. Biol and Med., 71:490, 1949). Vitamin K_3 was added to the control diet (50 µg./gm.) by inclusion into the fat-soluble vitamin mixture. In the feeding experiments with decanal, this compound was incorporated into the above diet at a level of 5 gm. per kilo of diet mixture.

Johnson-Type Beef Diet

88.0	gm.	whole beef (including drippings) cooked 25 min. in an autoclave at 15 lb. pressure
19.0	"	sucrose
35.0	"	corn starch
1.5	"	cod liver oil
0.5	"	wheat germ oil
4.0	"	salt mixture 446
5.0	"	vitaminized cerelose
153.0	"	

This diet is that reported by Metta and Johnson in their Progress Report No. 12, November 20, 1957. No vitamin K_3 was included in the vitaminized cerelose. Other contractors have established the use of B_0 to indicate 35% of diet solids as fresh frozen beef and B_6 to indicate similar amounts of beef irradiated at 6×10^6 r. These designations have been used throughout this report.

TABLE I (Continued)

SLU B Diet

88.0	gm.	whole beef (including drippings) cooked for 25 min. in an autoclave at 15 lb. pressure
19.0	"	sucrose
35.0	"	corn starch
2.0	"	salt mixture 3A
2.0	"	salt mixture 3B
5.0	"	vitamin B-complex mixture
2.0	"	fat-soluble vitamin mixture
153.0	"	

The salt and vitamin mixtures in this diet are those indicated in the SLU purified casein diet. No vitamin K_3 was added to the fat-soluble vitamin mixture.

Table II

WEIGHT CHANGES AND PROTHROMBIN TIMES

(SLU DIET, SLU RATS)

Diet	No. of rats	Body weight (gms.) Start	8 weeks
SLU + K	5	43.6	263.
SLU	5	43	245.

(Prothrombin times (seconds)

Diet	4 weeks	5 weeks	7 weeks
SLU + K	18.5* (15.8-20.2)	17.0 (16.2-19.5)	16.2 (15.4-16.8)
SLU	20.6 (18.4-25.5)	16.6 (15.7-17.7)	18.1 (15.7-20.5)

*Data in parentheses indicate range.

Table III

WEIGHT CHANGES AND PROTHROMBIN TIMES

(SLU DIET, SLU RATS) WITH RESTRAINT

Diet	No. of rats	Body weight (gms.) Start	8 weeks
SLU + K	3	60.5	214.
SLU	3	61.0	215.

Prothrombin times (seconds)

Diet	9 weeks	10 weeks*	11 weeks
SLU + K	19.1 (18.4-19.7)	44.9 (32.5-57.3)	20.5 (18.3-22.6)
SLU	18.6 (16.4-20.6)	220.5 (156.-285.)	17.7 (16.2-19.2)

*Dicumarol-sensitivity test, see Methods.

Table IV

WEIGHT CHANGES AND PROTHROMBIN TIMES OF SLU RATS ON SLU DIETS + 0.5% DECANAL

Diet + 0.5% decanal	No. of rats	Body weight (gms.) Start	8 weeks
SLU + K	5	47.	273.
SLU	5	46.	269.

Prothrombin times (seconds)*

Diet	11 weeks	12 weeks**
SLU + K	18.9 (16.7-20.8)	44.2 (38.1-51.9)
SLU	21.2 (18.6-23.6)	67.1 (58.8-81.0)

*Only 3 rats were studied in each group.
**Dicumarol sensitivity test.

Table V

WEIGHT CHANGES AND PROTHROMBIN TIMES IN RATS FED JOHNSON TYPE BEEF DIETS (SLU RATS)

Diet	No. of rats	Body weights (gms.) Start	8 weeks
B_6	46	46.9	296.7
B_o	42	49.6	317.9

Individual prothrombin times after 13 weeks on the respective diets

On Johnson-type B_6 Animal No.	Time sec.	On Johnson-type B_o Animal No.	Time sec.
3	41.5	2	24.5
5	56.5	4	80.6
11	22.9	6	38.0
12*	192.2	11	23.9
13	56.4	17	31.4
20	28.3	19	23.9
21	23.5	20	40.8
22	98.0	22	24.4
23	30.7	23	29.9
24	63.9	24	47.8
25*	113.6		
Ave.	66.1 (23-192)	Ave.	36.5 (23.9-80.6)

*Died of hemorrhage due to heart puncture.

Table VI

WEIGHT GAIN AND PROTHROMBIN TIMES OF RATS ON SLU B_6 AND SLU B_o (SLU RATS)

Diet	No. of rats	Body weight (gms.) Start	8 weeks
SLU B_6	7	46.5	309.6
SLU B_o	5	45.3	328.8

Prothrombin times (seconds)*

Diet	10 weeks	11 weeks**
SLU B_6	19.2 (18.5-20.2)	224. (68.-480.)
SLU B_o	23.4 (20.4-26.4)	578. (382.-738.)

*Determination on only 3 rats in each group.
**2.5 mg. Dicumarol/rat. (Dicumarol sensitivity test).

Do-12
(End)

Progress Report No. 2

MECHANISM OF THE HEMORRHAGIC PHENOMENON PRODUCED IN MALE RATS BY FEEDING OF IRRADIATED BEEF

By

Susan J. Mellette, M. D.
Louis A. Leone, M. D.

Department of Medicine
Medical College of Virginia

Contract No.: DA-49-007-MD-951

Period: 15 September 1958 to 15 March 1959

THIS IS NOT A FINAL REPORT. CONCLUSIONS STATED ARE SUBJECT TO CHANGE ON THE BASIS OF ADDITIONAL EVIDENCE. INFORMATION CONTAINED HEREIN IS NOT TO BE REPRINTED OR PUBLISHED WITHOUT WRITTEN PERMISSION FROM RESEARCH AND DEVELOPMENT DIVISION, OFFICE OF THE SURGEON GENERAL, DEPARTMENT OF THE ARMY, WASHINGTON 25, D. C.

ABSTRACT

Hemorrhagic death has been repeatedly produced in rats receiving diets containing 35% (dry weight) 6 x 10^6r) irradiated beef, starch, sucrose and a vitamin mix without Vitamin K. Both beta-irradiated beef, stored in the frozen state, and gamma-irradiated beef, stored at room temperature, have resulted in comparable mortality. Repeated studies of coagulation factors have revealed a progressive decline in both "true" prothrombin and in accelerator globulin (Factor V) followed by death in all male rats. Several females, surviving the irradiated diets, initially had very low levels of coagulation factors which improved over a period of weeks although feeding was continued.

The experiments involving castrate animals have now been completed. Castration of the male animal increased resistance to the development of the hemorrhagic syndrome. Coagulation factors were initially higher in these animals and deaths were delayed; however all orchiectomized males had died after nine weeks, compared to five weeks for intact males. Conversely, castration of the female resulted in death in all animals within nine weeks, in contrast to a 70% survival of intact females even after more than twenty weeks of feeding. Changes in coagulation factors during the course of the experiment were in all cases consistent with the final fate of the individual animal.

Incorporation of wheat germ oil and cod liver oil in the diets increased the rate at which deaths occurred in both male and female groups when compared with animals fed diets in which the vitamin oils had been omitted and oral supplements of vitamin A, D, and E given. Even in animals on control diets, the presence of the vitamin oils in the diet increased the number of abnormal levels of prothrombin as well as the degree of abnormality in males during the first six weeks. By sixteen weeks, differences between the two diets were no longer apparent. A comparable difference in coagulation factors occurred in females consuming irradiated diets with and without vitamin oils, but time relations were of a different order.

Studies have been performed on the relationship of concomitant vitamin E deficiency to hemorrhagic death. Dialuric acid hemolysis of erythrocytes occurred consistently in animals fed diets containing irradiated beef and the vitamin oils but only occasionally in animals on other diets. The data available at this time suggests that an animal is less likely to survive a low level of prothrombin if he is also vitamin E-deficient, as measured by dialuric acid hemolysis. This may be one of the factors explaining the survival of most of the male animals on control diets even when prothrombin levels averaged 20% and were as low as 13% of normal.

Further studies confirmed the abnormality of prothrombin and accelerator globulin in the growing male rat fed a cooked non-irradiated beef diet. Parallel studies on growing males fed a stock laboratory diet revealed that levels of accelerator globulin vary with the age of the animal, being higher in young and in mature animals than in those of intermediate size. Values are not, however nearly so low as those found in animals fed beef diets.

Typical hemorrhagic deaths have been produced in adult male rats (350 gm.) after only 7 days of irradiated beef feeding. Mel-2

INTRODUCTION

The present report involves further studies on the hemorrhagic syndrome associated with the feeding of certain diets containing irradiated beef to rats. It includes a study of the effect of control and irradiated beef diets on coagulation factors of intact and castrate male and female rats. Data from the first three weeks of feeding on this experiment has been previously reported, (Progress Report No. 1). The present report records the changes which occurred over a period of 20 weeks. Additional studies during the period of this report include evaluation of the effect on coagulation factors of the inclusion of the vitamin oils (wheat germ oil and cod liver oil) in the diet compared to comparable diets in which supplements of vitamins A, D, and E were given orally to both male and female rats. The likelihood of the development of a concomitant vitamin E deficiency in animals fed diets of the original Johnson type has also been evaluated. In addition, studies have been carried out in order to establish "normal" levels of accelerator globulin in the male rat on a stock laboratory diet at various stages of growth.

EXPERIMENTAL

1. Animals: All animals used thus far have been obtained from Charles River Laboratories (CD strain). Feeding experiments were begun at approximately 125 gm. body weight in the experiments in which castrations were performed because of time allowed for recovery from the operative procedures. Younger animals were used in subsequent experiments.

2. Diet: Two types of beef have been used. In Experiment I, beef obtained from Dr. C. M. McCay, beta irradiated (6 million rads) in June, 1957 at High Voltage Laboratory was employed. Both control and irradiated samples had been stored in cellophane packages in the frozen state. Gamma irradiated beef from the Savannah River facility became available to us in August, 1958 and the irradiated material (6×10^6r) has been stored at room temperature. The first feeding experiments with this material began after approximately three months storage.

2. Diet (continued)

Non-irradiated beef has been stored in the frozen state. Beef cooked at 14 pounds pressure for 25 minutes has been incorporated into diets similar to those originally used by the Illinois group with the following constituents - all gm/kg dry weight of diet: Beef (control or irradiated) 350, sucrose 190, corn starch 350, cod liver oil 15, wheat germ oil 5, salt mix (Wesson's) 40, and dextrose-vitamin mix 50. The dextrose-vitamin mix has the following composition: thiamin 2.5, riboflavin 2.5, niacin 10, pyridoxine 2.5, calcium pantothenate 20, PABA 50, inositol 100 and choline 1,000; all mgm/kg/dry diet.

In experiments in which the vitamin oils were omitted, the sucrose and corn starch components of the diets were increased proportionately. Diets are prepared about once weekly and in recent experiments fresh food has been given every other day with the remaining food being discarded at that time. Other details of feeding and animal care have been previously described.

3. Methods: Oxalated blood is obtained using siliconized equipment by cardiac puncture during nembutal anesthesia. The following determinations have been performed:

(a) Prothrombin concentration: Method of Hjort, Rapaport and Owren (J. Lab. and Clin. Med. 46:89,1955).

(b) Accelerator globulin (Factor V): Method of Lewis and Ware as modified by Carroll, (Tocantins, L. M. (ed.). The Coagulation of Blood-Methods of Study, Grune and Stratton, New York, 1955).

(c) Fibrinogen: Method of Quick in The Physiology and Pathology of Hemostasis, Philadelphia, 1951, Lea and Febiger.

(d) Dialuric acid hemolysis of erythrocytes: Method of Friedman, et als, "Bioassay of Vitamin E by the dialuric acid hemolysis method", J. Nutr. 65:143,1958.

RESULTS

1. Changes in Coagulation Factors During Several Months of Feeding of Beef Diets

A. Male Animals

1. Control beef diets:

(a) Experiment I

As previously reported, our initial experiments confirmed the observations first made by Witt, Kraybill and Read that abnormal levels of coagulation factors may occurr in male rats fed non-irradiated beef diets without vitamin K supplementation. In order to evaluate the results of the irradiated beef feeding, it was felt to be of considerable importance to obtain some understanding of the sequence of changes on non-irradiated beef diets as well as the irradiated diets. The present report (See Tables 2 and 4) demonstrates the changes which occur with time during continued feeding of control beef diets. Although greatly abnormal levels of prothrombin persisted throughout the 6th week in all but one male animal examined, considerable improvement had occurred by the 8th week andat 16 weeks the level of only one intact animal of the 5 males examined remained seriously low. Orchiectomized male animals on control diets, with generally better levels initially, also demonstrated a similar improvement with time, all levels being normal at 8 weeks and remaining so at 16 weeks. Accelerator globulin (Factor V) levels remained low (in many cases considerably lower than initially) for a longer period, including the 8th week in both intact and castrate males, but all had improved and were approaching normal by 16 weeks. At least 2 deaths which could be attributed to hemorrhage occurred in intact males on control diets in the experiment. No castrate males died and sacrifice of these animals after the 16th week revealed no significant pathology.

(b) Experiment II

Two other groups of male animals were started on control beef diets in November 1958. In one of these groups the diet composition was identical to that of Experiment I except that control beef obtained in cans with a lot irradiated at the Savannah River facility was fed to these animals. The differences between this experiment and the first using Dr. McCay's long-stored surplus beef are indicative of the importance of differences in the character of the beef used and may partially explain variations between the results of different investigations using "Johnson-type" diets. With irradiated beef diets, because of the marked depression of coagulation factors and rapid death, these differences are not so readily apparent in the male rat. Results in male animals in this experiment are shown in Table 8. Coagulation factors were not nearly so depressed during the early week of this experiment but, rather than becoming normal by 16 weeks as had previously occurred in Experiment I, most of the prothrombin levels were still decreasing at 16 weeks. Changes in accelerator globulin were less remarkable with a suggestion of improvement at the 16 week period.

1. Changes in Coagulation Factors During Several Months of Feeding of Beef Diets - continued

B. Female Animals

1. Control beef diets:

(a) Experiments I and II

Results are detailed in Tables 3, 5 and 9. In over 100 determinations of both prothrombin and AcG in females on control diets over a 20 weeks period in Experiment I and 19 weeks in Experiment II, no significant abnormality of coagulation factors was found. Levels of AcG were lower during the 6-9 weeks period than initially in both experiments as also noted in the male groups, but all were improving in later determinations. Such cyclic changes in the levels of coagulation factors during growth and development indicate the difficulty of evaluating isolated determinations during an experimental period.

2. Irradiated beef diets:

(a) Experiments I and II

Although female rats are certainly more resistant to death during irradiated beef diets, abnormalities of coagulation factors are not at all uncommon. 50 to 60% of all females in both experiments had prothrombin levels of less than 70% of normal at some time during the experiment. As occurred also in the male groups during Experiment II, there was a decline from essentially normal levels during the first weeks of feeding to low concentrations, followed in most cases by later improvement. In all of the studies of changes in coagulation factors with time, the variation between animals is obvious; but relatively consistent results are obtained in an individual animal.

2. Effect of Incorporation of Wheat Germ Oil and Cod Liver Oil Into Diet on Prothrombin and Accelerator Globulin Levels and on the Development of Indications of Concomitant Vitamin E Deficiency

The incorporation of the vitamin oils into the diet was early felt to be a factor in the development of the hemorrhagic syndrome. (Metta and Johnson, Progress Report # 12). These investigators, however, later (Progress Report # 14) reported that further experiments failed to substantiate this relationship. In the meantime, the MRNL group demonstrated that unsaturated fats in the diet in the form of corn oil did increase the mortality. Destruction of vitamin E in irradiated beef diets was demonstrated during the early stages of the Irradiated Foods Program (Poling and Reber, 1955). The problem in the present situation has been (1) To determine whether a vitamin E deficiency actually developed in the animals fed the diet under consideration and (2) To evaluate any relationship of such a deficiency to the occurrence of hemorrhagic death.

2. Effect of Incorporation of Wheat Germ Oil and Cod Liver Oil Into Diet on Prothrombin and Accelerator Globulin Levels and on the Development of Indications of Concomitant Vitamin E Deficiency (continued)

Adequate Vitamin E levels are of importance in the maintenance of vascular integrity; an exudative diathesis is one indication of deficiency in some species. In the present situation, vascular changes may be contributing to the development of hemorrhage since many investigators agree that some vascular defect must be present in association with hypoprothrombenemia for bleeding to occur, (c.f., Spaet, Blood 7:641,1952).

In preliminary studies during Experiment I, it was noted that spontaneous hemolysis of erythrocytes occurred on standing in samples obtained from animals given intraperitoneal injections of menadione bisulfite but not in samples from other animals. Hemolysis of erythrocytes, even with the development of haemoglobinuria has been shown to occur after the injection of Vitamin K substitutes in Vitamin E-deficient rats but not in rats on stock diets. (Allison, Moore and Sharman, Brit. J. Haematol. 2: 197,1956).

With this indication that a concomitant vitamin E deficiency was present in our experimental animals, a more thorough study was begun. The degree to which erythrocytes, in vitro, are hemolysed by dialuric acid was selected as a test for early vitamin E deficiency. In this method, the hemolysis resulting from dialuric acid is compared with that obtained by complete hemolysis with distilled water and that occurring spontaneously in cells incubated in buffer. It has been frequently shown that significant abnormalities in this test can be obtained in the rat after only a week or two on a vitamin E deficient diet. Unfortunately, as also frequently reported, results may be somewhat erratic from day to day primarily because of the ease with which dialuric acid hemolysis may be inhibited by non-specific factors. In our experiments, this was found to be true: but the differences between groups was consistent from on set of determinations to another and, furthermore, in over fifty separate determinations performed on cells from normal male rats on stock laboratory diets, hemolysis as great as 5-6% of the total was found on only three occasions, in all other instances the dialuric acid and spontaneous hemolysis being essentially the same.

Results of the hemolysis tests are shown in Tables 6 and 7. In Table 6, it will be noted that hemolysis occurred in the majority of the samples of blood obtained from animals on irradiated diets containing the vitamin oils, but to a lesser degree in samples from animals receiving irradiated diets without cod liver oil and wheat germ oil but given oral supplements, and in specimens obtained from rats receiving control beef diets. These findings are certainly not unexpected but may have littel significance in relation to the hemorrhagic syndrome unless a correlation exists between hemorrhagic death and a concurrent vitamin E deficiency. In Table 7, the most recent data from all the irradiated beef fed animals in each group in which determinations of coagulation factors and hemolysis were performed on the same sample of blood are tabulated.

2. Effect of Incorporation of Wheat Germ Oil and Cod Liver Oil Into Diet on Prothrombin and Accelerator Globulin Levels and in the Development of Indications of Concomitant Vitamin E Deficiency (continued)

Obviously, no definite conclusions can be drawn from so little data, but it is of some interest, for example, that in the vitamin oil diet group, rats # 2 and 8 with prothrombin concentrations of 15 and 20% but with insignificant hemolysis, have survived, whereas rats # 3, 4 and 1, with prothrombin concentrations of 23, 18 and 19% of normal, but with increased rates of hemolysis, died hemorrhagic deaths. The only hemorrhagic death which occurred in the vitamin-supplemented group (Rat #5) occurred with a very low prothrombin, but it is of interest that this animals also appeared to be E-deficient in spite of presumably adequate oral supplements.

The effect of incorporation of the vitamin oils into the diets on mortality is shown in Table 1. Changes in coagulation factors are recorded in Tables 8 and 9. It will be noted that deaths occurred more rapidly in male animals on diets containing irradiated beef with wheat germ oil and cod liver oil: 4 deaths occurred in this group during the first 4 weeks of feeding compared to only one in the group receiving oral supplements. By 12 weeks, however, 7 of the 8 animals in each group had succumbed to hemorrhage.

Even on the control diets, the presence of the vitamin oils in the diets increased the number of abnormal levels of prothrombin as well as the degree of abnormality in males during the first six weeks. By 16 weeks, the difference between the two diets was no longer apparent. No significant differences in accelerator globulin levels were noted.

In the female groups, no differences between the diets was apparent in animals fed non-irradiated beef. In irradiated beef-fed groups, mortality was higher when the diet contained vitamin oils. At 12 weeks, the differences were not significant; but since that time two additional females on the irradiated beef-vitamin oil diet have died, making a total of 50% deaths in this group compared to only one hemorrhagic death out of the eight animals in the diet without oils and with vitamin supplements. So far as coagulation factors are concerned, it would appear that any difference during the first few weeks is in favor of the vitamin-oil containing diet. During the 10-12 week and 14-15 week periods, however, more abnormal levels occurred and the levels tended to be lower in females fed the irradiated diets containing wheat germ oil and cod liver oil.

As suggested in Progress Report L, some of the differences in mortality and in coagulation factor levels between groups may be related to differences in weight gain. A similar situation pertains in comparing the diets under consideration. During the first week of feeding, male animals fed diets containing the vitamin oils gained 70 gm on the control diet and 68.5 gm on the irradiated diet compared to 59.9 and 62.5 respectively on the diets without oils. Comparison between groups would have been more satisfactory if appropriate oils rather than carbohydrate had been substituted for this 1.5% of the diet. Weight gains were, however, not so well sustained in the animals fed wheat-germ oil, cod-liver oil-containing diets and by 120 days, average weights of the animals in the two control-beef groups were almost identical.

3. Effect of Hormonal Factors on Development of the Hemorrhagic Syndrome

The effect of castration of male and female rats on coagulation factors and the occurrence of hemorrhagic death was one of several factors under consideration in Experiment I. Results after approximately three weeks feeding were previously reported. Subsequent data confirmed the conclusions reached at that early date: that castration of the male rat increased the resistance of the animal to the development of the hemorrhage syndrome, whereas the oophorectomized female was rendered highly susceptible. Differences, however, proved to be largely those of degree. Mortality data are shown in Table 1. "Hemorrhagic death" is considered to have occurred if gross and/or histopathological evidence of hemorrhage was found. Since cardiac puncture could, obviously, be a contributing factor, the relatively few animals in which death followed cardiac puncture were not considered to have died a "hemorrhagic death" unless the prothrombin level was less than 15% of normal in the sample obtained at the time of puncture. A very few animals were lost apparently as a result of cardiac puncture but if prothrombin concentration were normal and no evidence of hemorrhage present in the rest of the body, these were not considered to have been "hemorrhagic deaths".

It will be noted in Table 1 and in the several tables (2,3,4 and 5) listing coagulation factors, that a progressive decline in coagulation factors followed by death occurred in all animals on the irradiated beef diets except the intact females. In this group, three deaths (33%) occurred from hemorrhage. As already mentioned, a somewhat greater death rate (4 of 8 animals) has occurred after 19 weeks in a second experiment in which intact females were fed a diet similar in all respects except for the lot of beef used. The differences in condition of these two experiments have been outlined. Such results do, however, indicate that the resistance of the female animal to the hemorrhagic syndrome is a quantitatively limited phenomenon.

4. Coprophagy and the Hemorrhagic Syndrome

The studies herein reported were surely not intended as a substitute for quantitative studies in which feces weights during the prevention of coprophagy could be compared with those in which it was permitted. It was felt, however, that, if greatly different quantities of feces were consumed by groups of animals on different treatments but on comparable food intakes, such differences might well be reflected in the amount of feces remaining in the pans. Two sets of experiments were carried out. In the first (see "B" in Table 10) feces were collected from the animals in the various experimental groups over two periods of two days each. Female animals weighed about 250-300 grams and males around 400. The results given are average feces weight per rat per day. Feces weights from animals on the irradiated diets are somewhat greater in both male and female animals with a considerably greater difference in the male animals suggesting, as does the data of Metta and Johnson, less coprophagy on irradiated diets, at least in the male. It would appear that no great difference exists in the female animals either in relation to the presence or absence of vitamin oils in the diet, or to the irradiation of the beef.

Mel-9

52249 O—60—pt. 1——24

4. Coprophagy and the Hemorrhagic Syndrome (continued)

In later study, one surviving male animal from the original irradiated diet group and four females were studied during separate periods of irradiated and control beef feeding. Periods were three days each. In the data given, one initial irradiated beef period, three consecutive control beef periods and a later irradiated beef period have been included. Since the results during the irradiated beef periods were similar, they have been considered together and averages given are feces weights per day. Feces were air dried to constant weight in an oven at approximately 100°C. These data are recorded under "A", Table 10.

It would appear, as in the previous experiment, that a significant difference occurred between the irradiated and control diets in the one male animal studied. This, as well as the somewhat greater feces weights during the irradiated beef periods in three of the four female animals may well be due to a decrease in coprophagy. Food intake was somewhat less in females on the irradiated diet, but, as is well known and as is also apparent from the data presented, factors other than food consumption contribute to the total fecal output. The one animal (FB 5) in which feces weight was lower during the irradiated diet periods also ate less of the irradiated food; but it is of some interest that this animal was the only one of the eight rats in her original experimental group to consistently maintain normal levels of prothrombin during the previous prolonged irradiated beef feeding.

It is conceivable that individual differences in coprophagy may be of some importance in accounting for the spread of values of coagulation factors and differences in susceptibility to hemorrhage found amoung animals within experimental groups. Even if differences in coprophagy between male and female animals do exist, it would appear unlikely that this could entirely account for the difference in hemorrhagic deaths between the two sexes. That coprophagy could be influenced by hormonal differences is not, however, inconceivable. Differences in olfactory acuity have been correlated with the sex hormones and the well-known propensity of the pregnant female for unusual foods is undoubtedly related to endocrine changes.

5. Accelerator Globulin Levels and the Hemorrhagic Syndrome - Studies on Changes in Accelerator Globulin (and Prothrombin) During Growth in the "Normal" Male Rat

In the previous progress report, it was stated that the low levels of accelerator globulin found in the present study must be related to some phenomenon other than vitamin K deficiency since this factor is not known to be affected by dietary K deficiency or by vitamin K antagonists, at least at stages short of a "toxic" effect on the liver. Very little information is, however, available on "normal" coagulation factors in the rat. Standard curves for our own studies had been derived from samples from mature animals of both sexes.

5. Accelerator Globulin Levels and the Hemorrhagic Syndrome - Studies on Changes in Accelerator Globulin (and Prothrombin) During Growth in the "Normal" Male Rat (continued)

It was felt essential to determine whether changes during growth, such as those found in animals on non-irradiated beef diets, might not also occur in males on stock diets.

40 male animals of body weights varying from 60 up to 300 grams were obtained, placed on Purina chow, and determinations of coagulation factors performed. The very low levels of prothrombin found in intact males on control beef diets were not encountered in animals fed the stock diet, even in the youngest animals studied. All values for initial prothrombin determinations in "normal" males ranged from a low of 73% (one animal) to 103% with a mean of 93%, based on the original "100% value" of the mature animals.

As will be noted in the experimental data tables, most females on control beef diets have levels in excess of "100% of normal". Although growing females on stock laboratory diets have not been studied to the same extent as the males, it would appear that prothrombin levels are consistently somewhat lower during growth in the male than in the female rat, regardless of diet. This difference is not marked once full maturity is reached.

The observation that accelerator globulin levels in animals on control beef diets were frequently lower during about the 6th to 10th week than those obtained earlier in the experiment has already been mentioned. In animals fed Purina chow, males with body weights of less than 125 gm or more than 375 grams also tended to have considerably higher levels of accelerator globulin than animals of intermediate weights. When cardiac punctures were repeated on these animals over a period of about six weeks, a further decline was noted in all but one of the smaller animals, whereas levels greater than those found initially were obtained in animals which had reached about 400 grams by the time of the second determination. This further indicates that the changes which occur are related to age and body size rather than to diet alone or to the possible effects of repeated cardiac puncture.

The lower levels of accelerator globulin found during the intermediate growth phase in male animals on the stock diet did not, however, approach the very low levels occurring in animals dying of the hemorrhagic syndrome. An average of 68% of the "mature animal normal value" was found in ten animals weighing from 125 to 375 grams compared with 85% in the younger and around 100% in fully mature animals. In irradiated beef-fed animals dying of hemorrhage, especially after the first two or three weeks, levels of 18-40% of normal were most commonly found. The original premise, therefore, is unchanged: serious abnormalities of accelerator globulin occur in association with hypoprothrombenemia and hemorrhagic death.

5. Accelerator Globulin Levels and the Hemorrhagic Syndrome - Studies on Changes in Accelerator Globulin (and Prothrombin) During Growth in the "Normal" Male Rat (continued)

In view of the reported association between low levels of accelerator globulin and methionine deficiency, a preliminary experiment was performed in which methionine was administered parenterally to three animals on nine occasions over a period of 11 days. Determinations of coagulation factors were performed prior to the first intraperitoneal injection and on days 1, 4 and 11 of the experiment. Some improvement in accelerator globulin levels did occur during the course of the experiment in all methionine-treated animals, but not in the controls. Prothrombin levels followed an inverse pattern after the first injection: declining in the experimental animals, whereas control were improving. At day 11, prothrombin levels of two of the treated animals were also considerably higher but both accelerator globulin and prothrombin had returned to levels essentially similar to the preliminary values 5 days after the last injection of methionine.

6. Plasma Fibrinogen Levels have been detemined in 25 animals on both control and irradiated diets. No definite abnormalities were found and there was considerable variation in values obtained. There is a suggestion that the levels are moderately increased in animals with hypoprothrombenemia.

7. Irradiated Beef Feeding to the Adult Male Rat

Although it has been previously believed that younger males are more susceptible to hemorrhage death than mature animals, this does not appear to be necessarily true. Six male animals of approximately 350 grams each were begun on the irradiated beef diet eight days ago. Four of these have died spontaneously with typical hemorrhages involving the thymus and scrotal areas. Prothrombin concentrations are too low to be measured in the remaining two animals.

Personnel

Other personnel working on this project during the period of this report include:

Ann C. Powell, B. S., Laboratory Specialist A

Walter O. Cowan, B. S., Laboratory Specialist A

Martha Bourne, M. T., Laboratory Specialist A

Histopathological studies are being performed by Dr. Saul Kay, Chairman, Division of Surgical Pathology.

Dr. Henry G. Kupfer, Chairman, Department of Clinical Pathology, has served as consultant for the coagulation factor studies.

Table 1

Hemorrhagic Deaths During 12 Weeks of Feeding of Beef Diets

Experiment I - Diets containing vitamin oils - intact and castrate rats, McCay beef

Week		1	2	3	4	5	6	7	8	9	10	11	12	Tot./# Rats
Males														
intact	B-0	0	0	0	0	0	1	0	1	0	0	0	0	2/10
	B-6	0	5	3	0	2	-	-	-	-	-	-	-	10/10
castrate	B-0	0	0	0	0	0	0	0	0	0	0	0	0	0/10
	B-6	0	0	4	0	0	2	0	0	4	-	-	-	10/10
Females														
intact	B-0	0	0	0	0	0	0	0	0	0	0	0	0	0/10
	B-6	0	0	2	0	0	0	0	0	1	0	0	0	3/10
castrate	B-0	0	0	0	0	0	0	0	0	0	0	0	0	0/10
	B-6	0	1	4	2	0	1	0	0	2	-	-	-	10/10

Experiment II - All intact rats, diets with and without vitamin oils, QM beef

Males														
WGO-CLO	B-0	0	0	0	0	0	1	0	0	0	0	0	0	1/8
	B-6	0	0	2	2	2	1	0	0	0	0	0	0	7/8
A,D,E (o)	B-0	0	0	0	0	0	0	0	0	0	0	0	0	0/8
	B-6	0	0	1	0	4	2	0	0	0	0	0	0	7/8
Females														
WGO-CLO	B-0	0	0	0	0	0	0	0	0	0	0	0	0	0/8
	B-6	0	0	0	0	0	0	0	0	0	1	0	0	1/8
A,D,E (o)	B-0	0	0	0	0	0	0	0	0	0	0	0	0	0/8
	B-6	0	0	0	0	0	0	0	0	0	0	0	1	1/8

Table 2

Changes in Plasma Prothrombin During First 16 Weeks of Beef Diets

Male Animals - Experiment I

Prothrombin - % of Normal (Method of Hjort et als)

	Week	Rat #	11	17	36	37	32	43	22	25	Average
Intact B-0	2-5		16	21	21	13	22	22	23	19	20
	6		21	23	90	21	24	16	21	18	29
	8		83	86	87	80	80	43	47	-	72
	16		80	103	-	63	106	-	22	-	75
		Rat #	21	15	28	8					
B-6	2-4		21	19	-4	-4					12
	5		-4	19	-	-					11

(All intact B-6 animals dead by Day 34)

		Rat #	12	6	34	38	4	1	42	7	9	29	
Castrate B-0	2-5		40	43	100	103	23	21	28	87	16	-	51
	8		87	97	103	94	83	-	-	96	-	97	94
	15-16		103	83	-	83	90	106	110	93	106	103	97
		Rat #	24	18	5	13	26	16	23				
B-6	2-5		50	16	11	77	106	100	87				64
	6		23	21	-	20	23	-4	13				17
	9		-4	-4	-	-	-4	-	-				-4

(All castrate B-6 animals dead by Day 63)

Table 3

Changes In Prothrombin During First 20 Weeks of Beef Diets

Female Animals - Experiment I

Prothrombin - % of Normal (Method of Hjort et als)

	Week	Rat #	38	20	3	39	1	42	14	6	4	11	Averag
Intact													
B-0	2-5		110	77	93	103	107	100	110	97	98	88	98
	6		-	113	110	107	113	107	113	100	110	110	109
	7		-	110	107	106	108	110	113	113	113	116	111
	20		-	116	113	-	-	-	116	106	103	116	112
		Rat #	7	24	33	18	26	9	16	17	5	2	
B-6	2-5		21	103	77	93	110	70	17	-4	-4	13	51
	8		53	110	100	103	113	-	73	-	43	-	85
	9		113	110	113	113	116	108	113	-	37	-	103
	20		70	-	76	73	107	100	103	-	-	-	88

	Week	Rat #	12	8	43	27	19	30	21	25	32	Averag
Castrate												
B-0	2-5		93	103	73	93	77	113	85	97	107	93
	9		100	103	-	95	87	103	93	103	73	95
	15		-	103	-	103	-	-	-	-	-	103
		(Other animals sacrificed at 12 weeks)										
		Rat #	22	31	37	23	40	29				
B-6	2-5		17	16	-4	22	12	97				28
	6		-	13	-	22	-	12				16
	9		-	-4	-	-4	-	-				-4
		(All B-6 castrate animals dead by Day 63)										

Mel-16

Table 4

Changes In Accelerator Globulin (Factor V) During First 16 Weeks of Beef Diets

Male Animals - Experiment I

AcG - % of Normal (Method of Lewis and Ware)

	Week	Rat #	11	17	36	37	32	43	22	25	Average
Intact B-0	2-5		64	49	36	45	76	36	-	38	49
	6		48	31	27	32	26	22	30	19	29
	8		40	49	45	42	51	30	44	-	43
	16		81	77	-	71	68	-	74	-	74
		Rat #	21	15	28						
Intact B-6	2-4		97	73	60						76
	5		38	38	-						38

(All intact B-6 animals dead by Day 34)

	Week	Rat #	12	6	34	38	4	1	42	7	9	29	Average
Castrate B-0	2-5		40	79	100	100	45	39	38	83	12	-	60
	8		32	34	39	41	40	-	-	35	-	30	36
	15-16		50	94	-	81	86	56	40	46	61	52	63
		Rat #	24	18	5	13	26	16	23				
Castrate B-6	2-5		100	58	100	64	62	75	67				75
	6		39	52	-	33	40	42	27				39
	9		34	18	-	-	40	-	-				31

(All castrate B-6 animals dead by Day 63)

Table 5

Changes In Accelerator Globulin (Factor V) During First 20 Weeks of Beef Diet

Female Animals - Experiment I

AcG - % of Normal (Method of Lewis and Ware)

	Week	Rat #	38	20	3	39	1	42	14	6	4	11	Average
Intact B-0	2-5		100	54	66	42	100	100	100	84	89	100	84
	6		-	95	97	68	77	71	62	58	51	100	75
	7		-	97	73	45	100	61	61	75	45	48	67
	20			87	100	100	-	-	100	100	57	86	90
		Rat #	7	24	33	18	26	9	16	17	5	2	
Intact B-6	2-5		44	26	52	100	58	79	69	72	44	49	59
	8		51	87	46	51	60	-	55	-	49	-	57
	9		68	98	79	32	79	80	100	-	94	-	79
	20		100	100	96	52	74	100	72	-	-	-	85

	Week	Rat #	12	8	43	27	19	30	21	25	32	Average
Castrate B-0	2-5		83	100	72	91	90	54	100	85	85	84
	9		44	41	-	52	57	77	81	50	50	57
	15		-	100	-	64	-	-	-	-	-	82

(Other animals sacrificed at 12 weeks)

		Rat #	22	31	37	23	40	29	Average
Castrate B-6	2-5		100	71	55	60	96	100	80
	6		-	36	-	42	-	79	52
	9		-	33	-	33	-	-	33

(All B-6 castrate animals dead by Day 63)

Table 6

Effect of Diet on Dialuric Acid Hemolysis of Erythrocytes in Vitro

	# Dets.	Dialuric acid Hemolysis Greatest degree of hemolysis %	Significant hemolysis (greater than 5%) #	%
Female Rats				
12 weeks feeding				
Control beef-WGO,CLO	17	11	3	18
Irrad. beef-WGO,CLO	16	43	11	69
Control beef-AIE supp.(o)	17	6	1	6
Irrad. beef-AIE supp.(o)	17	21	2	12
20 weeks feeding				
Control beef-WGO,CLO	6	2.5	0	0
Irrad. beef-WGO,CLO	5	93	5	100

Table 7

Relationship Between Dialuric Acid Hemolysis,

Coagulation Factors and Hemorrhagic Death

Female Animals - Experiment II

IRRADIATED BEEF DIETS

Wheat Germ Oil and Cod Liver Oil in Diet					No Vitamin Oils in Diet oral supplements A,D,E				
Rat	Prothrom.%	AcG%	Hemol.%	Fate	Rat	Prothrom.%	AcG%	Hemol.%	Fate
1	19	68	9	Dead	1	20	24	0	Alive
2	15	64	6	Alive	2	21	68	0	Alive
3	23	42	34	Dead	3	43	33	0	Alive
4	18	56	43	Dead	4	93	48	0	Alive
5	103	100	6	Alive	5	11	42	21	Dead
8	20	71	2	Alive	6	100	78	0	Alive
					7	20	72	0	Alive
					8	96	48	0	Alive

Table 8

Prothrombin and AcG Changes During 16 Weeks of Feeding of

Beef Diets With and Without Vitamin Oils

Intact Male Animals - Experiment II

	Week	Rat# 1	2	3	4	5	6	7	8	Ave.	# abnorm*	% abnorm*
B-0 Prothrombin:												
WGO,CLO	2-6	70	100	19	93	113	93	57	87	79	2/8	= 25
in diet	16	37	57	-	50	70	23	87	80	58	4/7	= 57
A,D,E												
supp. (o)	2-6	103	103	73	103	113	87	106	100	99	0/8	= 0
	16	40	50	37	107	53	33	70	33	53	6/8	= 75
Accelerator Globulin:												
WGO,CLO	2-6	74	75	64	35	52	50	47	100	62	2/8	= 25
in diet	16	88	92	-	71	50	62	60	85	73	0/7	= 0
A,D,E												
supp. (o)	2-6	64	45	100	100	67	100	67	40	73	2/8	= 25
	16	100	100	71	70	50	50	63	59	70	0/8	= 0
B-6 Prothrombin:												
WGO,CLO	2-3	17	-	-	21	15	-	-	47	25	4/4	= 100
in diet	5-6	-	-	-	-	4	-	15	83	-	2/3	= 67
	11	-	-	-	-	-	-	-	17	-		
A,D,E												
supp. (o)	2-3	-	4	-	37	-	100	-	73	50	2/4	= 50
	6	80	-	4	-	-	-	-	-	-	1/2	= 50
Accelerator Globulin:												
WGO,CLO	2-3	50	-	-	62	35	-	-	42	57	2/5	= 50
in diet	5-6	-	-	-	-	23	-	61	49	45	2/3	= 67
A,D,E												
supp. (o)	2-3	-	46	-	95	-	44	-	52	57	2/4	= 50
	6	47	-	49	-	-	-	-	-	48	2/2	= 100
	11	53	-	-	-	-	-	-	-	-		

*Prothrombin "abnormal"=less than 70% of normal

AcG "abnormal"=less than 50% of normal

Mel-21

Table 9

Prothrombin Changes During 19 Weeks of Feeding of

Beef Diets With and Without Vitamin Oils

Intact Female Animals - Experiment II

	Week	Rat# 1	2	3	4	5	6	7	8	Ave.	# abnormal*		% abnormal*
B-0													
WGO,CLO in diet	3-7	110	110	113	73	110	103	112	-	104	0	=	0
	10-12	-	-	-	93	100	100	113	-	101	0	=	0
	14-15	107	90	-	117	110	113	113	-	109	0	=	0
	19	110	103	-	120	120	107	116	-	113	0	=	0
A,D,E supp. (o)	3-7	113	113	113	90	107	116	116	-	110	0	=	0
	10-12	-	113	100	116	100	120	106	-	109	0	=	0
	14-15	-	113	116	110	116	-	-	116	114	0	=	0
	19	-	107	120	90	120	120	120	120	114	0	=	0
B-6													
WGO,CLO in diet	3-7	-	60	103	-	73	103	87	100	88	1/6	=	17
	10-12	19	50	23	18	103	87	-	-	50	4/6	=	67
	14-15	-	15	-	16	107	15	-	87	58	3/5	=	60
	19	-	83	-	-	110	-	-	20	71	1/3	=	33
A,D,E supp. (o)	3-7	110	38	57	87	20	116	-	90	74	3/7	=	43
	10-12	83	116	110	-	11	100	20	96	77	2/7	=	29
	14-15	20	21	110	93	-	97	73	-	69	2/6	=	33
	19	113	70	37	83	-	100	20	-	70	2/6	=	33

* "abnormal" level = less than 70% of normal prothrombin

Table 10

Feces Weights of Animals on Control and Irradiated Beef Diets

A. Individual Animals on alternate control and irradiated beef diets (see text)

Rat #	Food intake Control	Food intake Irradiated	Feces Weights Control	Feces Weights Irradiated	% Change
MB 8	27	30	0.77	1.32	+71
FB 5	22	15	0.41	0.36	-12
FB 2	26	20	0.41	0.52	+26
FD 1	27	26	0.52	0.59	+13
FD 4	22	20	0.39	0.44	+13

B. Feces Weights - Groups of Male and Female Animals

A. Male Animals	Control Period I	Control Period II	Control Ave.	Irradiated Period I	Irradiated Period II	Irradiated Ave.
WGO,CLO in diets	0.75	0.88	0.81	1.33	1.20	1.27
A,D,E supp. (o)	0.83	0.90	0.87	1.33	3.20	2.27
Average both diets			0.84			1.77
B. Female Animals						
WGO,CLO in diets	0.58	0.60	0.59	0.55	0.70	0.63
A,D,E supp. (o)	0.47	0.87	0.67	0.75	0.90	0.83
Average both diets			0.63			0.73

Mel-23
(End)

Progress Report No. 11

THE NUTRITIONAL ADEQUACY AND PROBABLE TOXICITY OF FOODS PRESERVED BY IONIZING RADIATIONS

By

Norman F. Witt, Ph.D., Chairman, Chemistry Department
University of Colorado
Boulder, Colorado

Herman F. Kraybill, Ph.D.*
Merrill S. Read, Ph.D., Chemistry Division
William S. Worth, M.S. " "
Harold M. Trabosh, B.S. " "

U. S. Army Medical Research and Nutrition Laboratory
Fitzsimons Army Hospital
Denver 30, Colorado

With Technical Assistance of:

Pfc. Richard C. Dickerman, B.S.
Pvt. Edmond A. Goidl, Lic. Bioch.
Pvt. Delmont M. Hopkins, B.S.
Pfc. Richard A. Nelson, B.A.
Pvt. Richard W. Pospistle, B.S.
Pvt. William R. Roberts, B.S.
M/Sgt. Robert P. van Almen

*Present Address:

Engineering Department
Curtiss-Wright Corporation
Princeton Division
Princeton, New Jersey

Contract No. DA-49-007-MD-549

Period: 1 September 1958 to 15 March 1959

THIS IS NOT A FINAL REPORT. CONCLUSIONS STATED ARE SUBJECT TO CHANGE ON THE BASIS OF ADDITIONAL EVIDENCE. INFORMATION CONTAINED HEREIN IS NOT TO BE REPRINTED OR PUBLISHED WITHOUT WRITTEN PERMISSION FROM RESEARCH AND DEVELOPMENT DIVISION, OFFICE OF THE SURGEON GENERAL, DEPARTMENT OF THE ARMY, WASHINGTON 25, D. C.

ABSTRACT

Feeding studies with a composite diet of 15 food items which had been irradiated (2.79 or 5.58 megarads) and stored for 3-6 months at 70° F. showed a progressive decrease in growth with increasing irradiation dosage. Thiamine supplementation had no beneficial effect; pyridoxine supplementation only partially overcame the decreased growth, whereas addition of a B-complex vitamin mixture prevented the growth differences. Serum glutamic-pyruvic transaminase activities decreased with increasing radiation dosage in those diets not containing pyridoxine. Liver xanthine oxidase activities were equal between diet groups. The total cecal coliform count in animals on the control diet were 11-13 times greater than in the 5.58 megarad diet group.

Enzyme studies in animals fed Johnson-type beef diets showed the liver cytochrome oxidase activity to be markedly increased in animals fed 5.58 megarad beef. Studies with animals fed K-deficient MRNL-type diets showed no differences in liver enzyme activities between any diet groups, but, in all cases, the liver cytochrome oxidase activity in the control group was considerably higher than any previously observed.

Studies were undertaken concerning hemorrhagic diathesis in male rats fed irradiated diets. Oral supplementation of 0.5-1.0 μgm per day of menadione largely prevented death in animals fed 5.58 megarad beef, but 4 μgm per day was required to maintain normal prothrombin times. Raw irradiated (5.58 megarad) pork does not induce hemorrhage in rats, but room temperature storage and/or cooking of the irradiated product does result in hemorrhagic death for the animal consuming it. Administration of bile acids will decrease or prevent the incidence of hemorrhage. Total cecal coliform counts indicate that the feeding of irradiated meats does not decrease the bacterial micropopulation.

Heat treatment of milk (90° C) produces a product having an LD_{50} value of 347 ± 99 which is approximately equivalent to 6 megarad milk. Treatment of milk with U.V. radiations provided a milk with an LD_{50} of 229 ± 52. The presence of hematoporphyrin increases the LD_{50} value 5 to 6-fold.

INTRODUCTION

This is the eleventh progress report concerning the effects of feeding diets containing irradiated foods upon the metabolism of experimental animals. This project is under the joint sponsorship of the U. S. Army Medical Research and Nutrition Laboratory, Denver, Colorado and the University of Colorado, Boulder, Colorado.

METHOD

The diets used in the composite diet (Military A Ration) studies were prepared according to the methods for the cooked diets outlined in Progress

CU-B

52249 O—60—pt. 1——25

Report No. 10. In those diets supplemented with the B-complex vitamins, a vitamin premix prepared according to the procedures outlined for our earlier subacute toxicity studies was added at the time of compounding the diets. Thiamine and pyridoxine were added to the food daily so as to provide 100 and 180 micrograms daily per rat.

The determinations of tissue and blood enzymes were performed employing techniques outlined in previous progress reports.

The studies concerning hemorrhagic diathesis were conducted using Johnson-type diets containing pork or beef as outlined in Progress Report No. 10. Vitamin K_3 (menadione) was administered orally five days a week in 0.2 ml. of corn oil. The bile acids were mixed in the diet to provide a total of 87 mg. per 30 gm. of diet. Two bile acid regimens were used:

(a) Desoxycholic acid alone.

(b) An equal mixture of desoxycholic, lithocholic and cholic acids.

The gross anaphylaxis studies were conducted as previously outlined. The heated skim milk was processed in a sealed container immersed for a total of 35 minutes in an oil bath at the desired temperature. Ultraviolet irradiation was accomplished with a Mineralite Model S-61 lamp either with or without a filter having a peak at 2537 Å.

RESULTS AND DISCUSSION

A. STUDIES WITH COMPOSITE DIETS

1. Growth

Growth curves for the animals on the four series of diets are presented in Figure 1. It may be readily seen that the growth of animals on the unsupplemented diets decreased roughly proportional to the radiation level, confirming our previous report. Supplementation with the B-complex vitamins resulted in equal growth among all three groups. This clearly indicates that the decreased growth on the irradiated diets was due to vitamin deficiencies. Supplementation with thiamine did not have any effect upon the relative growth performances. On the other hand, pyridoxine supplementation brought the growth of animals on the X and 2X diets closely together; neither equaled the control, however. These results were confirmed by statistical analysis of the weight gains vs. caloric consumption data (Table I). The data suggest that pyridoxine is a limiting vitamin in these studies, but it is not the only missing factor. Surprisingly, thiamine does not appear to be a limiting vitamin in the irradiated diets.

2. Liver and Blood Enzyme Activities

Serum glutamic-pyruvic transaminase (GPT) activities are presented in Table II. The data support the conclusions suggested by the

growth experiments. In both the unsupplemented (H) and thiamine supplemented (HT) series, the GPT activity decreased with increasing radiation dosage. Supplementation with either the B-complex vitamins (HV) or pyridoxine alone (HP) resulted in equal activities among all diet groups.

The activities of several other liver and serum enzymes are presented in Table III. No effects of radiation processed diets on liver endogenous respiration, cytochrome oxidase, or xanthine oxidase activities were observed. The latter (xanthine oxidase) results are particularly noteworthy inasmuch as this indicates that riboflavin is probably not the missing factor in the radiation preserved foods. The alkaline phosphatase data present another interesting picture. In the case of the HV series, both the liver and serum phosphatases exhibited a progressive decrease in activity with increasing radiation level. The H series, on the other hand, showed no change between the control and 2X irradiated diet groups insofar as the serum phosphatase was concerned, but showed the liver phosphatase to be increased in the irradiated group. No reason can presently be given for these findings.

3. Cecal Coliform Counts

As an adjunct to other experiments which will be described presently, coliform counts on the cecal contents of animals on the H-0 and H-6 diets were performed. It is well known that the microorganisms of the G. I. tract may, under certain conditions, synthesize large percentages of the vitamins required by the rat. The coliform bacteria of the cecum have been implicated in this synthetic role. An increase in the numbers of these bacteria in the animal fed the irradiated diet might help to overcome otherwise deficient conditions caused by radiation processing of food.

The results of this study are given in Table IV. The data show that the animals on the nonirradiated diet had 11-13 times as many coliform bacteria in the cecum as did the animals on the 2X diet. Whether the decreased bacterial count is due to the decreased vitamin content of the diet or is due to some other factor is not immediately apparent. Certainly the coliform bacteria are not compensating for deficiencies resulting from the radiation destruction of vitamins in the foods.

B. ENZYME ACTIVITIES IN RATS FED IRRADIATED MEATS

1. MRNL Diets

Previous experiments had suggested that feeding MRNL-type diets (35% meat solids, casein, cornstarch, corn oil, vitamins) containing irradiated, 70° F. stored beef caused an increase in liver cytochrome oxidase activity over that seen in comparable animals fed nonirradiated beef diets. Furthermore, omission of the corn oil from the diets eliminated these differences, but the liver enzyme activities were, in all

cases, considerably above those ordinarily seen in healthy animals. Since vitamin K has been extensively implicated as a component of the cytochrome system, it was decided to investigate the omission of vitamin K from the d Results of studies of this type are presented in Table V. No significant differences between diet groups were seen with any of the enzymes studied. However, once again cytochrome oxidase activity values obtained with both the irradiated and control groups were markedly elevated over the normal values seen previously. The elevated cytochrome oxidase activity in the control group suggests that vitamin K insufficiency may be playing a role in the elevated cytochrome oxidase activities reported in the past. If so, then this occurs in spite of vitamin K supplementation of the standard MRNL-type diets containing irradiated meats.

2. Johnson-type Diets

In order to investigate the effects of vitamin K deficiency on the liver cytochrome oxidase system, studies were initiated using Johnson-type beef diets. In order to eliminate the factor of variable food consumption between the irradiated and control diet groups, the control animals were pair-fed with the 5.58 megarad beef group. The results after eight weeks of feeding are presented in Table VI. As may be seen, the cytochrome oxidase activity for the control group was considerably higher than "normal", but, even so, for the irradiated group it was still more markedly increased. This suggests that vitamin K deficiency does cause alterations in the activity of the cytochrome system comparable to those reported on other irradiated diets. It is interesting in these studies that, although no difference between diet groups was seen insofar as liver alkaline phosphatase was concerned, again a marked decrease in the serum phosphatase as compared to the control group was readily discerned.

C. HEMORRHAGIC DIATHESIS

1. Beef

In preparation for studies employing C^{14}-labeled vitamin K, it became of interest to know how much vitamin K was required daily to prevent hemorrhagic diathesis in male rats fed Johnson-type beef diets. We therefore undertook a "titration" study employing graded amounts of vitamin K administered orally daily to the growing animals. The results of these studies are presented in Table VII. As has been pointed out by Johnson and co-workers, the nonirradiated beef diet (L-0) was not adequate to permit survival of all the animals nor to maintain normal prothrombin times. The administration of 0.5-1.0 ugm menadione per day prevented, to a large measure, the hemorrhagic death of animals fed the irradiated beef (compare L-6 with L-6A and L-6B). However, this amount of menadione did not maintain the prothrombin time within the normal range (13-16 sec.). In order to do the latter, a daily administration of 4 ugm of menadione was required.

2. Pork

In a previous report, we noted that raw frozen-stored irradiated (5.58 megarad) pork did not induce hemorrhage in rats fed Johnson-type diets. Cooking of the frozen-stored irradiated pork caused a rapid induction of the hemorrhagic syndrome. Interestingly enough, the feeding of cooked nonirradiated pork also precipitated the hemorrhagic state. Confirmation of this latter point as well as extension of our data to cover the room-temperature stored irradiated product was therefore undertaken. The data are summarized in Table VII; these results should be compared to those presented in Table IX in Progress Report No. 10. It may be seen that again a high incidence of hemorrhagic death was observed with cooked nonirradiated pork. This death rate was roughly equivalent to that produced by the feeding of raw ambient temperature-stored irradiated pork. Cooking of the latter product somewhat hastened the appearance of hemorrhagic diathesis in the experimental animals. In summary, our data indicate that irradiation of the pork does not, per se, cause hemorrhage in the animal consuming it. Consumption of the stored irradiated pork, either raw or cooked, does induce hemorrhage. Cooking of nonirradiated pork will also result in diets bringing about hemorrhagic death.

3. Addition of Bile Acids

Johnson and co-workers have shown that animals fed diets containing irradiated beef do not practice coprophagy as extensively as do animals on the nonirradiated diets. This is undoubtedly an important contributory factor to the hemorrhagic syndrome seen in rats. However, since this mechanism would have little role in human nutrition, it is important to determine whether other factors also function in the hemorrhagic disease. Efficient fat absorption is vital to the absorption of vitamin K. Fat absorption is apparently decreased in animals consuming irradiated foods, perhaps because of decreased emulsification of the irradiated fats. If the latter is the case, perhaps an increase in the natural emulsifying agents (bile acids) would exert a beneficial effect.

A pilot study along these lines was set up using the cooked, ambient temperature-stored 5.58 megarad irradiated pork diet described in the previous section, with the addition of 87 mg. of bile acids per 30 gm. of fresh diet. Calculations indicate that the rats actually consumed approximately 50 mg. of bile acids per day. The results of this pilot experiment (Table IX) indicate that protection was indeed provided by the dietary bile acids. A second, larger study using irradiated beef diets is now under way.

4. Cecal Micropopulation

Vitamin K is largely obtained by the rat by coprophagy. The vitamin K content of the feces, in turn, is due to bacterial synthesis in the cecum, probably from the action of coliform bacteria. Therefore, a significant decrease in the cecal coliform population as a result of

eating irradiated meats might have a marked effect on the nutritional balance of the host animal. The results of preliminary studies of this possibility are presented in Table X.

The addition of bile acids to the pork diets did not significantly alter coliform population in the cecum. This would suggest that the survival of the rats administered the bile acids was not due to bile acid-induced lysis of the cecal bacteria with concomitant liberation of vitamin K into the G. I. tract.

In the beef study, the animals were prepared by pair-feeding the controls with the irradiated diet group on an individual basis. The irradiated diet animals were taken in the terminal state, their pair-mates on the following day. It may be seen that apparently the animals on the irradiated diet had higher cecal coliform counts than those on the control diet. This is the converse of what would be expected if the diet had a detrimental effect on the microorganisms. Thus, decreased microbial synthesis of vitamin K would not appear to be an important facet of the total syndrome, at least insofar as the present data may be interpreted.

D. ALLERGENICITY OF IRRADIATED PROTEINS

1. Gross Anaphylaxis Experiments

For comparative purposes, a study was undertaken of the allergenic properties of ultraviolet irradiated and heat-treated milk proteins. Skim milk was used in these experiments to challenge guinea pigs sensitized with anti-milk rabbit serum. The technique has been described previously.

One sample of heat-treated milk (90° C.) was successfully tested (Table XI). The LD_{50} value obtained (347 ± 99) was approximately equivalent to skim milk treated with 6 megarad gamma radiation. Attempts to determine an LD_{50} for 120° C. milk failed, but provided a theoretically interesting death curve which we are investigating further. The results of these studies will be presented in a later report.

Several ultraviolet irradiated milk samples have also been tested. Three-hour exposure to ultraviolet rays (without a filter) changed the LD_{50} from 27 ± 4 to 229 ± 52. The latter is roughly equivalent to 5.5 megarad gamma irradiated skim milk. Addition of hematoporphyrin as a photosensitizer produced a milk with an LD_{50} of 1271 ± 299. The relative change here is somewhat greater than that effected by 9.30 megarad gamma irradiation. The six-hour ultraviolet radiation treatments were performed with a filter having a peak at 2537 Å. The resultant products were not greatly different from nonirradiated skim milk, even with a photosensitizer obtained from Merck and Company. Repetition of the six-hour treatment is under way with the filter omitted.

2. Chemical Changes

In order to more fully understand the chemical changes in the milk which might cause the observed differences in biological response, several chemical assays are being performed on the various milk samples tested in the guinea pigs. These include: viscosity, sulfhydryl and disulfide determinations, electrophoretic patterns, and sedimentation rates. A detailed report of these data will be presented in a later progress report.

A careful investigation of the changes in the sulfur-containing amino acids caused by radiation processing is also in progress. This study is still in the methodology stage. It has been established, however, that both free sulfhydryl and disulfide configurations are increased with increasing radiation dose.

ACKNOWLEDGMENTS

These investigations are under the joint sponsorship of the Office of The Surgeon General, the Office of the Quartermaster General, and the University of Colorado, Boulder, Colorado. The foods were prepared at the QMF & CI in Chicago and gamma irradiated at the Materials Testing Reactor at Arco, Idaho.

The authors are indebted to Mr. Gerhard Isaac for the statistical analyses reported and to Colonel Ludwig R. Kuhn and Mr. Orman L. Weiser for advice and assistance in the microbiology studies reported. The staff of the Analytical Branch very kindly did the diet analyses and nitrogen determinations used in interpreting the data. Mr. James E. Keller and Sp/4 Joe J. Rochioli provided valuable assistance in maintaining the animals used in all experiments.

TABLE I

WEIGHT GAIN, CALORIC CONSUMPTION, AND CALORIC EFFICIENCY OF MALE RATS RAISED ON COMPOSITE DIETS

Supplement	Radiation Dose	Weight Gain (gm.)	Caloric Consumption (Kilocalories)	Caloric Efficiency
a) None	0	262	4444	.0589
	X	233*	4155	.0561
	2X	209**	4059	.0515**
b) B-complex	0	270	4287	.0629
	X	283	4358	.0649
	2X	276	4424	.0623
c) Pyridoxine	0	260	4376	.0594
	X	245	4390	.0558*
	2X	239	4349	.0549**
d) Thiamine	0	273	4387	.0622
	X	240**	4264	.0562**
	2X	215**	4221	.0509**

* Significantly different from control at 5% level.

**Significantly different from control at 1% level.

TABLE II

SERUM GLUTAMIC-PYRUVIC TRANSAMINASE ACTIVITY IN MALE RATS RAISED ON COMPOSITE DIETS

Note: Sigma 505 method; units/ml serum expressed as average ± standard deviation

Supplement	Radiation Level		
	Nonirradiated	X-irradiated	2X-irradiated
None	24 ± 4	19 ± 4*	16 ± 4**
B-complex	22 ± 4	22 ± 6	22 ± 3
Pyridoxine	23 ± 5	26 ± 6	25 ± 4
Thiamine	25 ± 6	20 ± 6*	17 ± 6**

* Significantly different from control at 5% level.

**Significantly different from control at 1% level.

TABLE III

LIVER AND SERUM ENZYME ACTIVITY IN MALE RATS FED COMPOSITE DIETS

Units Per mg. Dry Weight
(Ave. ± s.e.)

	Unsupplemented Diet (H)		B-Complex Supplemented Diet (HV)		
	0	2X	0	X	2X
Liver:					
Hypotonic Endogenous	2.88 ± 0.08	2.78 ± 0.07	2.50 ± 0.10	2.21 ± 0.12	2.61 ± 0.20
Cytochrome Oxidase	272 ± 37	289 ± 24	272 ± 19	224 ± 9	250 ± 22
Xanthine Oxidase	1.09 ± 0.21	1.19 ± 0.20	-	-	-
Alkaline Phosphatase	1.27 ± 0.08	1.64 ± 0.10	1.42 ± 0.46	1.07 ± 0.27	0.96 ± 0.29
Serum:					
Alkaline Phosphatase	70 ± 10	66 ± 15	112 ± 24	103 ± 36	70 ± 17

TABLE IV

COLIFORM COUNTS OF CECAL CONTENTS OF MALE RATS RAISED ON UNSUPPLEMENTED COMPOSITE RATIONS

	Control	2X-irradiated
Age of Rat (Days)	90	93
Days on Diet	59	61
Rat Weight	301	267
Number of Rats	3	4
Coliform per gm. Cecal Material		
a) Average (X 10^5)	16.8	1.51
b) Range (X 10^5)	15.0 - 20.5	0.155 - 4.90
Coliform per Cecum		
a) Average (X 10^5)	58.1	4.39
b) Range (X 10^5)	40.3 - 83.7	0.454 - 13.1

TABLE V

LIVER AND SERUM ENZYME ACTIVITIES IN MALE RATS FED VITAMIN K-DEFICIENT IRRADIATED OR NONIRRADIATED BEEF DIETS WITH OR WITHOUT CORN OIL

Note: Activity Expressed Per Hour Per mg. N_2; Ave. ± s.e.

Enzyme	Radiation Dose (megarad)	With Corn Oil	Without Corn Oil
Hypotonic Endogenous (μl O_2)	0	24.2 ± 0.9	23.5 ± 0.4
	5.58	21.6 ± 1.2	22.4 ± 0.3
Cytochrome Oxidase (μl O_2)	0	2674 ± 148	2892 ± 170
	5.58	2538 ± 115	2881 ± 221
Liver Alk. Phosphatase (units)	0	14.2 ± 1.0	18.6 ± 3.7
	5.58	10.3 ± 1.6	15.1 ± 2.1
Serum Alk. Phosphatase (units)	0	68 ± 14	41 ± 15
	5.58	50 ± 16	67 ± 16

TABLE VI

LIVER AND SERUM ENZYME ACTIVITIES IN PAIR-FED MALE RATS RAISED ON HEMORRHAGE-INDUCING JOHNSON-TYPE DIETS

Note: Activity Expressed Per Hour Per mg. Dry Weight; Ave. ± s.e.

Enzyme	Nonirradiated	5.58 Megarad Irradiated
Hypotonic Endogenous (μl O_2)	2.86 ± 0.12	2.94 ± 0.14
Cytochrome Oxidase (μl O_2)	309 ± 16	358 ± 10
Liver Alk. Phosphatase (units)	3.10 ± 0.58	3.83 ± 0.33
Serum Alk. Phosphatase (units)	90 ± 4	45 ± 3

TABLE VII

TABLE VII

MINIMUM LEVELS OF VITAMIN K_3 TO OVERCOME HEMORRHAGIC DIATHESIS IN MALE RATS FED JOHNSON-TYPE BEEF DIETS

Note: Menadione administered daily in 0.2 ml. corn oil; positive and negative control animals received corn oil alone

	L-0	L-6	L-6A	L-6B	L-6C	L-6D
/ugm Menadione/Day	0	0	0.5	1.0	2.0	4.0
Number Rats	10	5	10	10	10	10
Deaths:						
0-14 Days	0	0	0	0	0	0
15-28 Days	0	4	0	0	0	0
29-42 Days	0	1	0	0	0	0
43-56 Days	1	-	0	1	0	0
57-70 Days	1	-	1	0	0	0
Total	2 (20%)	5 (100%)	1 (10%)	1 (10%)	0 (0%)	0 (0%)
Prothrombin Times in Seconds:						
Average	30	59	39	34	20	15
Range	15-57	14-116	25-75	22-48	14-36	13-18

TABLE VIII

DEATHS OF MALE RATS RAISED ON JOHNSON-TYPE DIETS CONTAINING AMBIENT-TEMPERATURE STORED IRRADIATED PORK

(Irradiation Level: 5.58 Megarad)

	Cooked		Raw
	Control	Irradiated	Irradiated
Number Rats Used	10	10	10
Number Dead During:			
0-14 Days	0	3	2
15-28 Days	5	6	5
29-42 Days	1	1	1
43-56 Days	1	0	0
57-70 Days	2	0	0
71-84 Days	1	0	1
Prothrombin Times (sec.)			
Mean	44	62	140
Range	15-180	14-180	53-180

TABLE IX

SURVIVAL OF MALE RATS RAISED ON JOHNSON-TYPE DIETS CONTAINING 70° F. STORED COOKED IRRADIATED PORK DIETS WITH OR WITHOUT ADDED BILE ACIDS

(Radiation Level: 5.58 Megarad; Bile Salts Approx. 50 mg./Day)

	Control	Irradiated	Irradiated + Desoxycholic Acid	Irradiated + Mixed Acids*
Number of Rats	20	10	3	3
Number Dead During:				
0-14 Days	0	3	0	0
15-28 Days	5	6	0	0
29-42 Days	3	1	0	1
43-56 Days	2	0	0	0
Total Number	10	10	0	1
%	50%	100%	0%	33%

*Equal weights of cholic, desoxycholic, and lithocholic acids.

TABLE X

CU-0

TABLE X

CECAL COLIFORM COUNTS IN MALE SPRAGUE-DAWLEY RATS RAISED ON DIETS CONTAINING COOKED IRRADIATED OR NONIRRADIATED FOODS STORED AT ELEVATED TEMPERATURES

Diet	Radiation Dose Megarep	No. of Rats	Counts (in Millions) Per: gm. Cecal Material Ave.	gm. Cecal Material Spread	Total Cecum Ave.	Total Cecum Spread
a) Laboratory Pellets	0	9	4.50	0.10 - 29.0	8.36	0.48 - 24.4
b) Pork + Bile Salts	5.58	4	6.04	0.10 - 15.0	12.0	0.20 - 27.4
c) Beef (Interim Data)	0	6	8.23	0.10 - 24.0	9.35	0.20 - 28.8
	5.58	6	157.0	1.40 -668.0	126.0	1.68 -467.6
d) Composite (15 Foods)	0	4	1.68	1.50 - 2.05	5.81	4.04 - 8.36
	6	4	0.15	0.016- 0.490	0.44	0.045- 1.31

TABLE XI

MEAN LETHAL SHOCKING DOSE (LD_{50}) FOR MILK-SENSITIZED GUINEA PIGS CHALLENGED WITH U.V. IRRADIATED OR HEAT-TREATED SKIM MILK

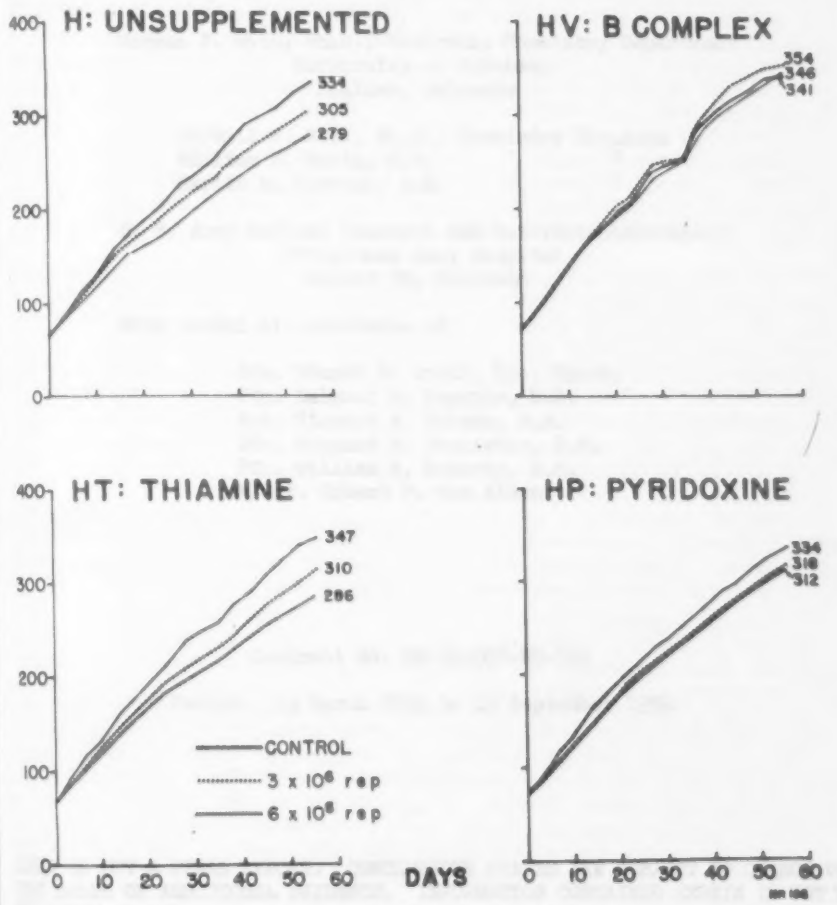
Treatment	Number of Guinea Pigs	LD_{50} /ugm Protein N Per Dose	Approximate Ratio Control vs. Treated
Heated Milk			
1. Control	55	24 ± 3)	1:14
90° C.	55	347 ± 99)	
U.V. Treated Milk			
2. Control	55	27 ± 4)	1:8
3 Hrs., No Sensitizer	53	229 ± 52)	
3. Control	55	26 ± 4)	1:49
3 Hrs., with Hematoporphyrin	81	1271 ± 299)	
4. Control	55	21 ± 2)	1:1.1
6 Hrs., No Sensitizer*	55	25 ± 7)	
5. Control	55	21 ± 3)	1:28
6 Hrs., Merck Sensitizer*	66	60 ± 7)	

*System contained filter which peaked at 2537 Å.

CU-Q
(End)

FIG. I

GROWTH OF MALE RATS RAISED ON COMPOSITE DIETS OF FIFTEEN COOKED IRRADIATED FOODS



52249 O—60—pt. 1——26

Progress Report No. 12

THE NUTRITIONAL ADEQUACY AND PROBABLE TOXICITY OF FOODS PRESERVED BY IONIZING RADIATIONS

By

Norman F. Witt, Ph.D., Chairman, Chemistry Department
University of Colorado
Boulder, Colorado

Merrill S. Read, Ph.D., Chemistry Division
William S. Worth, M.S. " "
Harold M. Trabosh, B.S. " "

U. S. Army Medical Research and Nutrition Laboratory
Fitzsimons Army Hospital
Denver 30, Colorado

With Technical Assistance of:

Pfc. Edmond A. Goidl, Lic. Bioch.
Pfc. Delmont M. Hopkins, B.S.
Sp4. Richard A. Nelson, B.A.
Pfc. Richard W. Pospistle, B.S.
Pfc. William R. Roberts, B.S.
M/Sgt. Robert P. van Almen

Contract No. DA-40-007-MD-549

Period: 15 March 1959 to 15 September 1959

THIS IS NOT A FINAL REPORT. CONCLUSIONS STATED ARE SUBJECT TO CHANGE ON THE BASIS OF ADDITIONAL EVIDENCE. INFORMATION CONTAINED HEREIN IS NOT TO BE REPRINTED OR PUBLISHED WITHOUT WRITTEN PERMISSION FROM RESEARCH AND DEVELOPMENT DIVISION, OFFICE OF THE SURGEON GENERAL, DEPARTMENT OF THE ARMY, WASHINGTON 25, D. C.

ABSTRACT

Feeding studies with a 15-item composite diet of irradiated or non-irradiated foods have confirmed the fact that oral thiamine supplementation has no beneficial results insofar as growth of rats fed the irradiated diet is concerned. Pyridoxine administration only partially overcomes the growth-depressant activity of the irradiated diet. However, simultaneous supplementation with both pyridoxine and thiamine caused both groups of animals to grow equally well. Studies with erythrocyte transketolase activity showed that consumption of the irradiated diet resulted in a decrease in activity. Pyridoxine supplementation did not increase the activity, whereas thiamine supplementation did return the enzyme to normal.

Liver enzyme studies in animals fed Johnson-type diets have shown that cytochrome oxidase activity is increased in animals fed the K-deficient irradiated diet. Supplementation with menadione or bile acids returned these values to normal.

"Titration" feeding studies with Johnson-type beef diets have shown that 6 µgm of Synkayvite per day are required to prevent hemorrhagic death and normal prothrombin times. Administration of bile acids in the beef diet decreases the death rate to about 50% in 70 days. The cecal coliform counts in animals fed the irradiated beef diets are essentially normal. In the case of cooked nonirradiated pork, addition of 1 µgm K_3 per gram of diet does not prevent death; oral administration of 20 µgm of K_3 per day does prevent death. This suggests that vitamin K is destroyed in the presence of cooked pork.

The allergenicity studies have shown that 105° C. treatment of raw skim milk results in a greater change in LD_{50} than does a 9.30 megarad gamma dose. Chemical data concerning the irradiated milks are presented and a proposed chemical mechanism to explain them is proposed.

INTRODUCTION

This is the twelfth progress report concerning the effects of feeding diets containing irradiated foods upon the metabolism of experimental animals. This project is under the joint sponsorship of the U. S. Army Medical Research and Nutrition Laboratory, Denver, Colorado, and the University of Colorado, Boulder, Colorado.

METHOD

The diets used in the composite diet studies were prepared according to the methods for the cooked diets presented in Progress Report No. 10.

Only two treatment levels were employed: frozen control and the "2K" radiation treatment. Thiamine-hydrochloride and pyridoxine were added to the food daily so as to provide 100 or 180 micrograms per rat, respectively.

The determinations of tissue and blood enzymes were performed, employing techniques outlined in previous progress reports. Erythrocyte transketolase activity was assayed by the modified method developed by Brin and Ostashever (private communication).

The studies concerning hemorrhagic diathesis were conducted using Johnson-type diets containing pork or beef as outlined in Progress Report No. 10. Unless otherwise specified, the irradiated meats (5.58 megarad) were stored 3-6 months at ambient temperature before diet formulation. Menadione diphosphate (water soluble vitamin K_3) was administered orally Monday through Friday in 0.2 ml. of water; the quantities are expressed as molecular equivalents of menadione. The bile acids were mixed in the diet to provide a total of 83 or 125 mg. per 30 gm. of diet. Two bile acid regimens were used as outlined in Progress Report No. 11.

The gross anaphylaxis studies were conducted as previously outlined. Viscosity measurements were performed by standard procedures. The sulfhydryl content of the irradiated milk was determined by the dead-stop end point titration procedure outlined by Larson and Jenness (J. Dairy Sci. 33: 890, 1950). Preliminary estimation of the disulfide bonds was made by application of a combination histochemical-paper strip chromatographic technique adapted from Thompson et al. (Amer. J. Path. - in press).

RESULTS AND DISCUSSION

A. STUDIES WITH COMPOSITE DIETS

1. Growth

Growth curves for animals on four series of dietary regimens are presented in Figure 1. As has been shown previously, pyridoxine supplementation improved the growth of animals fed the irradiated diet; thiamine supplementation alone had no effect. However, simultaneous supplementation with both pyridoxine and thiamine appeared to provide better growth than pyridoxine alone. This suggests that a synergistic effect between these two vitamins may occur in animals fed irradiated diets. Nevertheless, the growth of the animals fed the supplemented irradiated diets still did not quite parallel that of animals fed the control diets. Whether this reflects a statistical aberration or additional missing vitamins is not readily apparent. It was shown previously that supplementation with a complete water-soluble vitamin premix overcome the decreased growth of animals fed the irradiated diet.

2. Blood Enzymes

The deficiency of pyridoxine was confirmed previously by the application of serum glutamic-pyruvic transaminase assay to the experimental animals. Brin and associates (Progress Report dated 15 September 1958) have shown that erythrocyte transketolase activity is dependent upon thiamine sufficiency of the diet, the depressed activity appearing as early as nine days after feeding the deficient diet. We have confirmed these results in our laboratory using semi-synthetic diets. Normal value of approximately 1300-1500 γ pentose disappearance have been obtained with adult male rats. We have applied this system to red blood cells from rats fed the composite diets with the results shown in Table I. It may be seen that both the control and irradiated unsupplemented diets (S-0 vs S-6) gave below-normal transketolase values. Even so, the irradiated diet group had the lower value of the two. Supplementation with pyridoxine alone (SP-0 vs SP-6) had no effect upon the enzyme activity as would be expected. On the other hand, supplementation with thiamine, either alone (ST-0 vs ST-6) or in combination with pyridoxine (STP-0 vs STP-6), yielded essentially normal values. However, as pointed out above, only the double supplementation regimen provided approximately equal growth between the irradiated and control diet groups.

It thus appears that the erythrocyte transketolase values do not parallel the results of the growth tests. Whether the discrepancies between the two sets of data indicate a true case of vitamin interaction in rat metabolism (as manifested in growth), or some other explanation applies, is not yet definite.

C. HEMORRHAGIC DIATHESIS

1. Beef

Additional studies employing the titration technique have been completed to establish the requirement for water-soluble vitamin K_3 (Synkayvite). In this way, it was hoped that additional information on the role of fat absorption in the hemorrhagic phenomenon might be obtained.

The data from this experiment are presented in Table II. The results did not show what had been anticipated; i.e. that water-soluble K_3 might be more efficacious than fat-soluble K_3 in overcoming the syndrome. In fact, the reverse was true, as may be readily seen by comparing these data with that presented in Table VII in Progress Report No. 11. Whereas in the earlier study 1-2 μgm menadione prevented death and 4 μgm prevented prothrombin time elevation, the comparable figure for Synkayvite was 8 μgm for both indices. This once again demonstrates that vitamin K absorption is intimately related to lipid absorption. This fact unfortunately overshadowed the anticipated results from the Synkayvite experiment.

2. Pork

We have noted in previous reports that cooked nonirradiated pork induces hemorrhage in rats when compounded into Johnson-type diets. In order to round out these data, vitamin K supplementation was undertaken to confirm that this phenomenon was indeed similar to that obtained with cooked irradiated beef or pork. The results of these experiments are presented in Table III.

When the vitamin K was incorporated into the diet, even at a relatively high level (20 γ/day), it provided no protection against the hemorrhagic syndrome. On the other hand, a comparable quantity of vitamin K administered orally daily did protect the animals completely against the disease.

Several explanations of these data are possible. (1) An antimetabolite might be present in the cooked pork which prevents the utilization of the vitamin K supplement. This would appear improbable since oral administration of the vitamin at the same level provided protection. (2) Obstructed or impaired absorption from the G.I. tract would induce deficiency. This also would appear improbable for the same reason as stated above. (3) The vitamin K may be destroyed when in the presence of the cooked pork. This would appear to be the most logical conclusion, particularly in view of Johnson's report that a similar phenomenon occurs with cooked irradiated beef. Certainly, the destruction must be extensive as we have clearly shown that animals fed cooked irradiated beef require only 1-4 μgm of K_3 per day for survival and normal prothrombin activity.

3. Addition of Bile Acids

In our last progress report we presented preliminary data indicating that the addition of bile acids to Johnson-type irradiated pork diets afforded protection against the hemorrhagic syndrome. These studies have now been extended to include beef. The data are summarized in Table V.

Two levels of bile acids were used which provided the animals with approximately 83 or 125 mg. of bile acid per day. In either case, the death rate was decreased by 40-50% on each of the bile acid regimens. These data are interpreted as indicating that lipid emulsification and/or lipid absorption is impaired in the animals consuming the cooked irradiated beef. This, in turn, decreases the absorption of vitamin K from the already marginal diet.

It is interesting to note that a similar phenomenon may occur with the cooked control beef. Whereas we have routinely lost approximately 20% of the animals fed the control diet, addition of the mixed bile acids so as to provide a daily consumption of 125 mg. completely protected the animals from hemorrhagic death.

4. Cecal Micropopulation

The studies concerning the effect of feeding Johnson-type diets on the E. Coli content of the cecum of experimental animals have been completed. The data are presented in Table V.

In the initial experiment, the control group was pair-fed to the irradiated diet group. The data indicated that the terminal animals on the irradiated diet had an increased cecal micropopulation compared to the control animals. Whether this was due to the consumption of the irradiated diet or was a function of the failing health of the rats was not clear. Therefore, a second experiment was performed in which the irradiated diet animals were divided into two groups: (1) Non-terminal animals with prothrombin times over 40 seconds, and (2) terminal animals. The results show clearly that the non-terminal, K-deficient animals had cecal micropopulations which fell within the normal range. The terminal animals, on the other hand, had slightly increased micropopulations.

These results indicate that the cecal micropopulation is not influenced by the consumption of the Johnson-type irradiated beef diets. Therefore, the vitamin K synthesis by the microorganisms also probably is not influenced by the consumption of the irradiated diet. However, in the terminal state, a bacterial invasion may occur such as is well known for other disease conditions. This invasion probably is not related directly to consumption of the irradiated diet.

D. ENZYME ACTIVITIES IN RATS FED IRRADIATED BEEF

To further test the hypothesis that the elevated liver cytochrome oxidase activity observed in animals fed irradiated meats is related to marginal vitamin K deficiency, additional experiments using Johnson-type diets have been performed. The results of these studies are presented in Table VI.

It may be seen that the animals fed the Johnson-type diet have an elevated cytochrome oxidase activity much as has been seen in previous experiments employing MRNL-type diets. Oral supplementation with either menadione or Synkayvite brings these values down to normal. Furthermore, supplementation with the bile acids also lowers the liver cytochrome oxidase activity, further indicating the role that fat absorption has in conserving the limited amounts of vitamin K available in the Johnson-type diets. The hypotonic endogenous respiration was normal in all groups of rats.

Due to the somewhat impaired food consumption observed in rats fed the Johnson-type irradiated beef diets, the vexing problem of differing nutritional status still clouds the interpretation of these data. A new paired feeding approach employing all these materials is now in progress which should help in defining the role of vitamin K sufficiency in this enzymatic aberration.

E. ALLERGENICITY OF IRRADIATED PROTEINS

1. Gross Anaphylaxis Experiments

One additional sample of milk has been tested by this technique during this period. Raw skim milk which had been heated at 105° C. for 35 minutes in a closed system was found to have an LD_{50} of 909 ± 109 compared to a control value of 23 ± 4 providing a 39.5:1 ratio of change in allergenicity. This ratio is somewhat greater than the 31:1 ratio obtained with 9.30 megarad irradiated raw skim milk reported earlier (Progress Report No. 10, Table X).

Several new experiments are planned for the present period. We obtained data earlier showing that the 9.30 megarad radiation-distilled whole milk (courtesy of Dr. B. E. Proctor) had an LD_{50} comparable to approximately 4 megarad treatment (Arco) of raw skim milk. Several possible explanations for this difference are possible: (1) The M.I.T. milk was prepared from whole milk so that the butterfat may have exerted a protective effect upon the milk protein. (2) The M.I.T. milk that we tested was condensed during the course of irradiation. Proctor and Goldblith's group has shown that condensation of the milk during irradiation alters the post-irradiation gelling properties of the product. Therefore, the condensation of the sample provided to us might also have caused protection against protein alteration. (3) The concurrent distillation process removes many volatile compounds. It is possible that these compounds, if left in solution, cause further change in the milk protein. Their removal during irradiation would, of course, decrease or eliminate this phenomenon.

Radiation-distilled milk samples have been delivered to test hypothesis (2). Unfortunately, our guinea pig supplier has gone out of business so that new contacts will have to be made.

2. Chemical Changes

Past experiments have employed paper electrophoresis for establishing changes in the nature of milk proteins subjected to gamma or ultraviolet irradiation. Below 5.58 megarad, a decrease in all constituent proteins occurs, roughly proportional to radiation dosage. At 5.58 megarad and above, an essentially immobile component appeared in both the casein and whey fractions along with the diminution in the quantity of the normal milk protein constituents. At 9.30 megarad, only the non-mobile component was found. In the case of ultraviolet irradiation, at most only 7% of the total casein protein was converted to the immobile component after either 3 or 6 hours of irradiation.

These data suggest that, below 5.58 megarad of gamma radiation, degradation of the protein molecules occurs. Polymerization of both the whey and casein fractions becomes the dominant process at 5.58 megarad and above. Ultraviolet irradiation, on the other hand, results in only a small amount of polymerization in the casein fraction with no apparent polymerization of the whey proteins.

The viscosity data shed further light upon the changes taking place during the irradiation of milk protein. The data obtained with gamma-irradiated milk are presented in Table VII. It may be seen that a gradual increase in viscosity (from 1.498 to 1.574 centipoises) occurred with increasing dosage up to 5.58 megarad. Between 5.58 and 9.30 megarad the viscosity changed markedly, from 1.574 to 1.715 centipoises. It is possible that these changes might reflect an increasing molecular size, particularly between 5.58 and 9.30 megarad. This polymerization might, in turn, explain the dramatic decrease in biologic response observed between the latter two radiation levels. The viscosity measurements with the U.V. irradiated milk, presented in Table VIII, do not show any significant change in viscosity resulting from exposure to ultraviolet rays. This would suggest, then, that the alteration in biologic response seen following 3 or 6-hour periods of irradiation may be due to some factor other than molecular polymerization. Even the addition of hematoporphyrin did not induce marked viscosity changes during ultraviolet treatment.

The investigations of sulfur compounds in the gamma and ultraviolet treated milks provide further information on the nature of the reactions taking place. (See Tables IX and X.) As the radiation dose increased, significant increases in the sulfhydryl content were obtained with both types of radiation treatment. The change in the gamma-irradiated samples was most dramatic at 5.58 megarad and above, whereas in the ultraviolet treated samples, the sulfhydryl content was almost linearly related to exposure time. Both the photoactivators accentuated the production of sulfhydryls by ultraviolet irradiation. The histochemical-chromatographic procedure also demonstrated increases in sulfhydryl content as either the gamma or ultraviolet dosage increased. Furthermore, application of this procedure to disulfide estimation indicated that an increasing gamma-irradiation dose resulted in an increase in disulfide content. Tentative confirmation of this pattern has been obtained by quantitative chemical methods. Application of this method to the ultraviolet treated milk did not indicate any change in the disulfide content either with or without photosensitizers. In contrast to the data by Sliwinski and Doty (Ag. Food Chem. 6: 41, 1958), using gamma-irradiated beef protein, no increase in methyl mercaptan was observed when their method was applied to the gamma-irradiated skim milk samples.

From these analyses, it is evident that both gamma and ultraviolet irradiation result in a marked increase in sulfhydryl content of skim milk. Only gamma irradiation causes a simultaneous increase in disulfide bonds; the ultraviolet irradiation has no apparent effect. Several mechanisms might explain these findings. It is possible that methionine is converted in part to methyl mercaptan by splitting the thioether linkage on the protein side, thus accounting for the increased sulfhydryl content. However, this would appear improbable, at least for gamma irradiation, since no increase in methyl mercaptan was demonstrated. Methionine may also be degraded to form homocysteine. Two of the latter molecules could combine to form homocystine or an unsymmetrical disulfide could be formed between homocysteine and cysteine. This degradation-condensation scheme would account for the simultaneous

appearance of sulfhydryl and disulfide linkages following gamma irradiation. It may be that the energy transfer in ultraviolet irradiation lacks the intensity to initiate such a decomposition-condensation mechanism.

The data presented here suggest that ultraviolet irradiation and low levels of gamma irradiation result in the denaturation or destruction of milk protein with concomitant appearance of sulfhydryl linkages and alteration in antigenicity. Higher levels of gamma radiation probably cause the subsequent agglomeration of the protein fragments into new protein entities having different physical properties. This agglomeration is accompanied by an increase in both disulfide and sulfhydryl bonds, suggesting that the formation of -S-S-linkages may be at least partially involved in the polymerization. Furthermore, the markedly altered biological response to the high-level gamma-irradiated milk would appear to be correlated with the formation of the new protein polymers. The lack of formation of such polymers during ultraviolet irradiation might explain the less marked change in biological response to ultraviolet irradiated milk protein.

ACKNOWLEDGMENTS

These investigations are under the joint sponsorship of the Office of The Surgeon General, the Office of the Quartermaster General, and the University of Colorado, Boulder, Colorado. The foods were prepared at the QMF&CI in Chicago and gamma irradiated at the Materials Testing Reactor at Arco, Idaho.

The authors are indebted to Colonel L. R. Kuhn, Mr. O. L. Weiser and Pfc. T. W. Sundholm for advice and assistance in the microbiology studies reported. The staff of the Analytical Chemistry Branch provided continuing support in many phases of the work; Mr. LeRoy O. Matoush and Pfc. A. E. Fugarino are to be particularly commended for the sulfhydryl determinations on milk proteins. The Animal Service Branch provided valuable assistance in maintaining the animals used in all experiments.

TABLE I

ERYTHROCYTE TRANSKETOLASE ACTIVITIES IN MALE RATS FED COMPOSITE COOKED IRRADIATED DIETS

Note: Activities expressed as micrograms of ribose disappearing per hour per ml. of blood

Supplement	Control		2X-Irradiated	
	No. Rats	Ave. ± s.e.	No. Rats	Ave. ± s.e.
None: S	11	1167 ± 36	9	965 ± 3[illegible]
Thiamine: ST	10	1511 ± 49	10	1404 ± 5[illegible]
Pyridoxine: SP	9	1268 ± 30	9	1083 ± 4[illegible]
Thiamine Plus Pyridoxine: STP	5	1403 ± 48	5	1366 ± 5[illegible]

TABLE II

MINIMUM LEVELS OF VITAMIN K_3-DIPHOSPHATE NEEDED TO OVERCOME HEMORRHAGIC DIATHESIS IN MALE RATS FED JOHNSON-TYPE BEEF DIETS

Note: Synkayvite administered daily orally in 0.2 ml. water; doses are expressed as molecular equivalents of menadione

	R-6	R-6A	R-6B	R-6C	R-6D	R-6E	R-6F
µgm vitamin K_3/day	0	0.25	0.50	1.00	2.00	4.00	8.00
Number of Rats	10	10	10	9	10	10	10
Deaths:							
0-14 days	0	0	0	0	0	0	--
15-28 days	4	0	0	0	0	0	--
29-42 days	1	2	0	0	0	0	--
43-56 days	5	3	2	0	2	0	--
57-70 days	0	3	2	5	0	2	--
Total	10 (100%)	8 (80%)	4 (40%)	5 (55%)	2 (20%)	2 (20%)	0
Prothrombin Times in Seconds:							
Average	51*	96	41	26	21	22	14
Range	--	60-180	13-74	12-36	14-36	14-38	--

*Only few rats assayed due to rapid death and abundance of previous data.

TABLE III

DEATHS OF MALE RATS FED COOKED NONIRRADIATED PORK DIETS (JOHNSON-TYPE) SUPPLEMENTED WITH MENADIONE

Note: Rats received 20 µgm menadione per day either in diet or as daily oral dose in corn oil

	Unsupplemented	Vitamin K in Diet	Oral Vitamin K
Number of Rats Used	10	10	10
Deaths:			
0-14 days	0	0	0
15-28 days	5	1	0
29-42 days	1	4	0
43-56 days	1	1	0
57-70 days	2	2	0
Total	9 (90%)	8 (80%)	0 (0%)
Prothrombin Times (sec.)			
Average	44	46	13
Range	15-180	18-103	12-14

TABLE IV

DEATHS OF MALE RATS FED JOHNSON-TYPE OF DIETS CONTAINING COOKED BEEF SUPPLEMENTED WITH BILE ACIDS

	Nonirradiated		Irradiated				
	No Suppl.	Plus Three Bile Acids*	No Suppl.	Desoxycholic Acid		Three Bile Acids*	
Weight Bile Acids Consumed Per Day (mg.)	0	125	0	83	125	83	125
Number of Animals	15	10	10	10	10	10	10
Deaths:							
0-14 days	0	0	3	0	0	0	0
15-28 days	0	0	7	1	2	0	0
29-42 days	1	0	0	1	3	3	2
43-56 days	1	0	0	2	1	0	3
57-70 days	1	0	0	1	0	2	1
Total	3 (20%)	0 (0%)	10 (100%)	5 (50%)	6 (60%)	5 (50%)	6 (60%)
Prothrombin Times (sec.)							
Average	30	15	166	65	47	60	36
Range	14-57	10-34	59-180	11-180	10-180	12-180	10-180

*Equal weights of cholic acid, desoxycholic, and lithocholic acid.

TABLE V

CECAL COLIFORM COUNTS IN MALE SPRAGUE-DAWLEY RATS RAISED ON DIETS CONTAINING COOKED NONIRRADIATED OR IRRADIATED (STORED) BEEF

Regimen	Radiation Dose (megarad)	No. of Rats	E. Coli per Cecum (in Millions) Average	Spread
1. Pair Fed	0	12	15.81	0.08 - 157.0
	5.58	12	96.5	0.20 - 668.0
2. Ad lib	0	26	9.36	0.07 - 132.0
Non-terminal	5.58	16	2.60	0.35 - 14.30
Terminal	5.58	13	35.4	1.15 - 200.1

TABLE VI

LIVER CYTOCHROME OXIDASE ACTIVITY IN RATS FED JOHNSON-TYPE DIETS CONTAINING COOKED BEEF (AD LIBITUM)

Supplementation	µl Oxygen Consumed/Hours/mg. Dry Weight Control Diet	Irradiated Diet
None	256 ± 32	358 ± 26
Vitamin K Supplement (Oral)		
2 γ menadione/day	--	249 ± 38
1 γ Synkayvite/day	--	242 ± 1
4 γ Synkayvite/day	--	245 ± 45
Bile Acid Supplement		
83 mg. per day	--	292 ± 38
125 mg. per day	--	262 ± 67

TABLE VII

INFLUENCE OF GAMMA IRRADIATION ON THE VISCOSITY OF RAW SKIM MILK

Dosage (megarad)	Viscosity (centipoise)
0	1.498
0.465	1.533
2.79	1.574
5.58	1.574
9.30	1.715

TABLE VIII

EFFECT OF SENSITIZERS ON THE VISCOSITY OF ULTRAVIOLET IRRADIATED SKIM MILK
(All values expressed in centipoises)

Dosage	No Sensitizer	Hematoporphyrin	DDTPD
Control	1.377	1.392	1.391
3 Hour	1.380	1.347	1.406
6 Hour	1.412	1.430	1.408

52249 O—60—pt. 1——27

TABLE IX

INFLUENCE OF GAMMA IRRADIATION ON THE PROTEIN SULFHYDRYL CONTENT OF RAW SKIM MILK

Dose (megarad)	Sulfhydryl (mg. x 10^{-2})
0	4.30
0.465	4.39
2.79	4.81
5.58	7.21
9.30	11.75

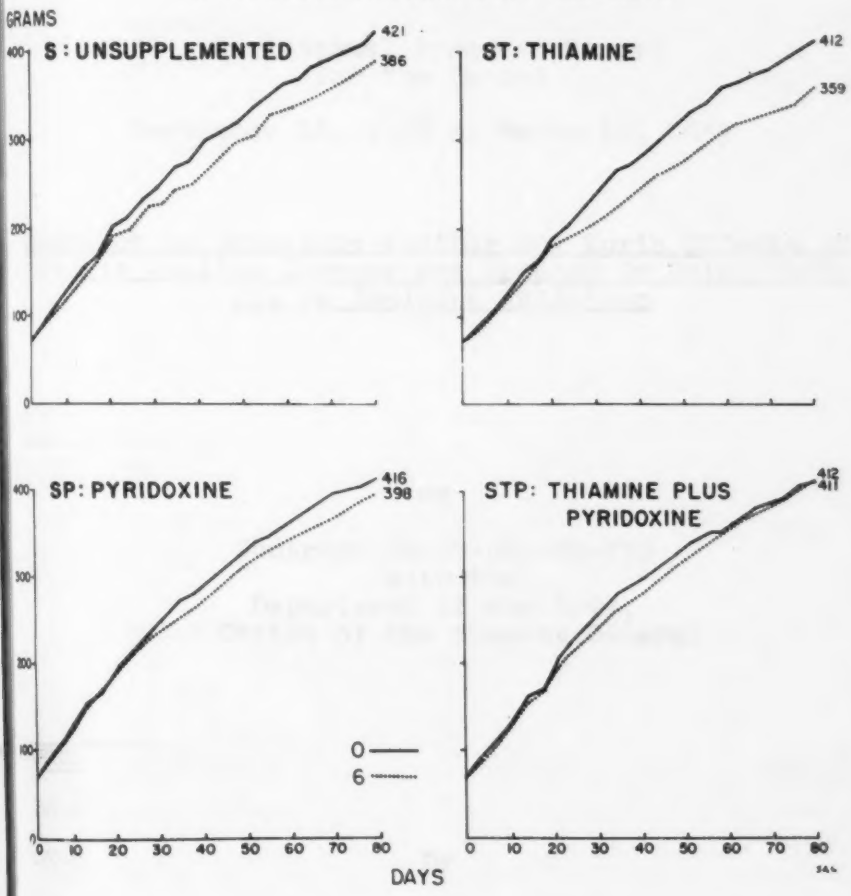
TABLE X

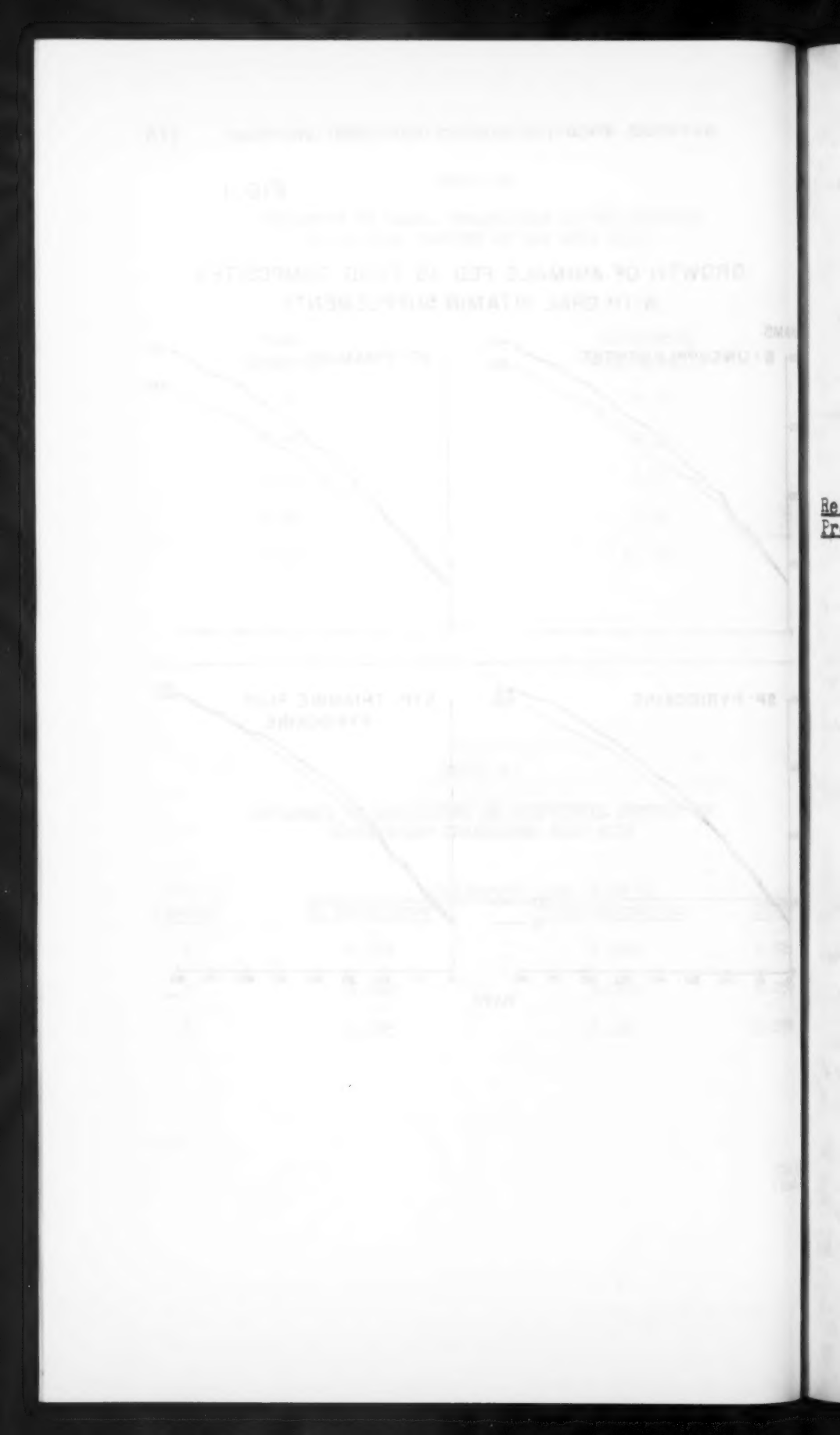
INFLUENCE OF SENSITIZER ON SULFHYDRYL CONTENT OF ULTRAVIOLET IRRADIATED SKIM MILK

Dose (Hours)	Sulfhydryl (mg. x 10^{-2})		
	No Sensitizer	Hematoporphyrin	DDTPD
0	4.525	4.902	4.525
3	5.840	9.050	9.050
6	9.145	13.198	12.070

FIG. 1

GROWTH OF ANIMALS FED 15 FOOD COMPOSITES WITH ORAL VITAMIN SUPPLEMENTS





DEPARTMENT OF FOOD TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASS.

Semi-Annual Progress Report
for the Period

September 14, 1958 to March 15, 1959

Research to Determine Whether Any Toxic Effects of Protein Quality Changes are Induced in Dried Whole Egg by Ionizing Radiation

on

Contract DA-49-007-MD-775
with the
Department of the Army,
Office of the Surgeon General

by

B. E. Proctor and S. Miller

March 15, 1959

The purpose of this study has been to investigate the effect of feeding irradiated dried whole eggs on reproduction and lactation in the dog. Details of the preparation of the eggs and of the breeding procedure are given in earlier reports. This report covers the period September 14, 1958 to March 15, 1959 on contract number DA-49-007-MD-775 with the Department of the Army, Office of the Surgeon General.

MAINTENANCE AND CONDITION

The clinical condition of the animals which have been fed for 4 years on irradiated whole dried eggs at a 20% level in the diet, continues to be good. No significant changes in weight have been observed except in the cases of pregnant animals as indicated in Table I. The lesions that had appeared between the toes of some animals have cleared up to some extent. This will be discussed at a later point in the report.

REPRODUCTION AND LACTATION

The data on estrus and breeding collected thus far are reported in Tables 2 and 3. All animals were bred at each estrus except in the instances noted.

Two pregnancies and whelpings took place during the period covered by this report. In group B,

animal number H 92 delivered a litter of three pups and in group D, animal number H 90 whelped a litter of three pups. All animals in both litters died 24 to 36 hours after birth. As in previous whelpings, gestation and parturition were normal and autopsy and histological examination of the tissues of the puppies revealed no evidence of any abnormality to which these neonatal deaths could be attributed. Hematological examination of the last three litters whelped, however, did give some evidence, for the first time, of possible metabolic derangement. As indicated in Table 4, all three litters suffered from a slight to severe anemia.

A newly born pup normally has a Red Blood Count (RBC) of over 8 million cells/cu.mm. The RBC in these pups has been approximately 3 million to 5 million cells per cu.mm. A possible abnormality also was found in the case of the White Blood Count (WBC). In the normal dog, the WBC should range from 8 thousand to over 12 thousand cells/cu.mm. In these pups, with the exception of one litter (H 97), the WBC has ranged from 21,800 to 29,500 cells/cu.mm. This is indicative of a severe leucytosis. When the RBC/WBC ratio is computed, (again with the exception of the H 97 litter), it is found that the ratio is considerably lower than the 600:1 to 700:1 normally found. It is in the leukocytic diseases that this syndrome of anemia combined with

leukocytosis is found. However there was no other clinical evidence to suggest this disease has been found. In addition, no evidence of this disease has been found upon autopsy.

A number of other possible explanations have been initiated to test two of these hypotheses. These are the possibility of a biotin deficiency and that of some genetic abnormality.

BIOTIN SUPPLEMENTATION

As has been previously reported, sufficient avidin remains in the spray dried whole egg used in these studies to cause biotin deficiency in rats fed a biotin free diet. It has also been noted that certain of the adult animals had developed lesions reminiscent of those found in a slight biotin deficiency. It is possible, therefore, that the abnormal response of the puppies in these experiments may be the results of a subtle manifestation of a biotin deficiency which has not evidenced itself in these puppies with the usual stigmata. There is some evidence that biotin plays a role in reproduction and development. Since the puppy has a higher metabolic activity than has the adult dog, it is conceivable that a deficiency in these young animals might not appear as clearly in the adults. These facts combined with the observation of a weak estrus and poor reproductive cap-

ability in two groups, the controls and one irradiated egg group, have added weight to the possibility of such a deficiency.

To test this, one male and one female in each group have received daily supplements of 0.25 mg of biotin orally. The results are, as of yet, inconclusive. There is, however, some indication that the lesions of the supplemented dogs are tending to clear up more quickly than those of the unsupplemented groups. Hair coat and appearance of the former groups appear to be somewhat better. The effect of this treatment on reproduction has not yet been determined. Blood assays for biotin as well as those for estrogens, androgens and gonadotrophins will be performed.

GENETIC ABBERATIONS

In order to test the possibility of inbred genetic difficulties in these dogs, a complete new study has been started with puppies obtained from the Allied Dog Farms, Fayetteville, Arkansas. The animals have been derived from differing lines with no common ancestor through the third generation. At least five animals from each litter have been obtained.

Nineteen of the 32 dogs ordered were received on February 21, 1959. Ages ranged from 10 to 14 weeks and included 11 males and 8 females. The animals are

currently being fed stock diet mixed with evaporated milk diluted with an equal volume of water. The condition of the pups appears to be good and their weights are recorded in Table 5. When the remaining 13 animals are received and become accustomed to the laboratory environment, the animals will be divided into four groups of 4 males and 4 females in each group as follows:

1. Diet control - this group will be fed the stock dog meal alone with no added eggs.
2. Egg control - This group will receive the stock dog meal supplemented with 20% unirradiated eggs.
3. 1×10^6 rep - Same as group 2 but with 20% eggs irradiated at 1×10^6 rep level.
4. 3×10^6 rep - Same as group 3 but with 20% eggs irradiated at 3×10^6 rep.

The animals in each litter will be divided as equally as possible among the various groups. Wherever it is feasible, breeding will be done outside the litter.

The addition of the diet control group permits an evaluation of the effect of relatively large quantities of eggs being fed.

The larger size of each group permits variations in the experimental protocol as new observations are made without destroying the value of the text in so far as standardized requirements for toxicity tests are concerned.

Table I

Table I

SUMMARY OF DOG WEIGHTS (LBS.)

Diet	Dog ear mark	on arri-val	0 week	135 wks	142 wks	146 wks	147 wks	150 wks	154 wks	156 wks	160 wks	165 wks
						males						
A	I 9	6.5	13.0	18.8	19.5	18.6	18.6	18.7	17.2	17.4	16.8	17.2
control	I 4	8.5	18.8	29.8	30.0	29.6	30.0	29.6	29.6	29.2	28.2	28.2
B-1x10^{-6} rep	H86	7.6	12.7	26.0	26.2	26.6	26.5	26.8	26.4	25.9	25.2	26.0
(air)	I 7	9.1	18.8	25.8	26.7	26.2	25.9	26.4	25.6	25.1	23.4	24.2
C-3x10^{-6} rep (air)	I 3	8.6	17.3	26.8	27.0	26.8	27.5	26.7	26.6	26.2	25.2	26.2
D-3x10^{-6} rep (vac)	H95	8.2	15.5	29.6	30.2	29.4	29.7	29.4	29.2	29.2	27.8	28.7
	I 2	6.3	14.6	26.4	27.1	26.4	26.6	26.5	25.4	25.6	25.4	25.4
						females						
A	H91	6.2	10.8	18.0	18.4	17.7	17.4	17.8	17.8	17.3	16.4	16.6
control	I 1	7.6	14.7	23.6	23.5	23.4	23.7	24.0	24.0	23.1	22.0	22.7
B-1x10^{-6} rep	H92	5.4	9.0	15.2	15.8	15.5	15.8	15.4	16.8*	14.0	13.0	13.4
(air)	H97	8.9	16.5	25.2	25.4	25.4	25.9	26.1	26.0	25.0	24.8	26.2
C-3x10^{-6} rep (air)	H89	6.3	10.8	17.7	17.7	17.8	18.0	18.2	17.8	17.8	17.0	17.4
	H98	7.4	14.7	24.5	23.6	23.6	24.0	23.6	22.5	22.5	22.2	23.3
D-3x10^{-6} rep (vac)	H90	7.3	13.2	21.2	22.3	22.0	21.8	24.2*	19.2	19.1	18.5	19.4
	H99	6.5	14.0	22.5	21.9	21.6	21.8	21.1	21.0	21.6	20.5	21.2

* Animal pregnant

TABLE II

Breeding Records

Group and No.	Service Estrus	Male	Dates	Comment	Artificial Insemination Male	Dates
A-control	8/20/56 - 9/17/56		No service			
H-91	3/25/57 - 4/22/57	19	4/9 - 4/12	Estrus weak, refused male		
	11/28/57 - 12/26/57	19	12/7-12/19	Estrus weak, refused male		
	7/19/58 - 8/16/58	19	7/29,30,31	Poor estrus, refused male	19	8/1,4,6
I-1	8/15/56 - 9/12/56		No service			
	4/5/57 - 5/3/57	14	4/19 - 4/26	Estrus weak, refused male		
	12/10/57- 1/7/58	14	12/17-12/31	Estrus poor, allowed mounting.		
	10/10/58- 11/7/58		animal ill	no service		
B-1x10^6 rep (air)	4/23/56- 5/14/56		No service			
H-97	10/1/56 - 5/14/56		No service	Animal ill		
	* 3/15/57- 4/12/57	H86	3/31	2x, 15 minutes each		
		17	4/1	1x, 20 minutes		
	* 9/17/57-10/15/57	H86	9/28-9/29	20 minutes each		
	* 4/21/58- 5/23/58	H86	5/4 - 5/5	20 minutes each		
	10/16/58-11/13/58		Not bred	Allowed to rest		
H-92	4/2/56 - 4/23/56		No service			
	10/22/56-11/19/56		No service	Animal ill		
	* 7/15/57- 8/12/57	H86	7/27-7/28	20 minutes each		
	* 9/27/58-10/25/58	H86	10/12-10/13	20 minutes each, female had to be held		

TABLE II
(cont'd)

TABLE II
(cont'd)

Breeding Records

Group and No.	Estrus	Service Male	Service Dates	Comment	Artificial Insemination Male	Artificial Insemination Dates
C-3x10^6 rep (air)	5/7/56 - 5/28/56			No service		
H-98	11/7/56 - 12/5/56	13	11/14	Estrus weak, no service		
	4/19/57- 5/17/57	13	5/2-5/10	Female nervous, poor service		
	10/19/57-11/10/57	13	10/28-11/6	Female nervous, poor service		
	4/27/58- 5/26/58	13	5/7,8,9,10,11	Good Estrus, male shy	13	5/13,14 unsuccessful
	10/11/58-11/8/58		No service	Male shy		
H-89	10/26/56-11/23/56		No service			
	7/6/57 - 8/3/57	13	7/23-7/24	20 minutes each		
	2/26/58 - 3/26/58	13	3/6,7,10,11 12,13,14	Good estrus, male shy	13	3/14,17 unsuccessful
	12/19/58-1/16/59	13	1/3-1/4	25 minutes each		
	9/5/56 - 10/1/56		No service			
	4/12/57 - 5/10/57	H95	4/26-4/27	25 minutes each		
	*11/6/57 - 12/4/57	12	11/18-11/20	20 minutes each		
	*9/10/58 -10/10/58	H95	9/14-9/15	20 minutes each		
H-99	6/11/56-7/9/56		No service			
	12/14/56-1/7/57	12	12/24-12/28	Female nervous		
	6/10/57-7/8/57	12	6/18,20,21	Female nervous		
		H95	6/19,22 28	Female nervous		
	11/27/57-12/22/57	12	12/14-12/15	20 minutes each		
	5/28/58-6/25/58	12	6/14-6/15	20 minutes each		
	12/9/58-1/6/59	12	12/26-12/27	25 minutes each		

TABLE III

Whelping Records

Animal No.	Estrus No.	Date Bred	Sire	Date Whelped	No. Males	No. Females	Total Pups	Comments
A-control								No pups
B-1x10^{6}rep (air)								
H-97	3	3/31/57-4/1/57	H86 or I 7	5/29/57 5/30/57	2	4	6	All dead by 6/15/57
H-97	4	9/28/57-9/29/57	H86	11/30/57	2	3	5	All dead by 12/2/57
H-97	5	5/4/58-5/5/58	H86	7/4/58	2	4	6	All dead by 7/7/58
H-92	3	7/27/57-7/28/57	H86	9/26/57	3	1	4	All dead by 9/30/57
H-92	4	10/12/58-10/13/58	H86	12/14/58	2	1	3	All dead by 12/16/58
C-3x10^{6}rep (air)								No litters
D-3x10^{6}rep (vac)								
H-90	3	11/18/57-11/20/57	12	1/22/58	3	2	5	All dead by 1/24/58
H-90	4	9/14/58-9/15/58	H95	11/15/58	2	1	3	All dead by 11/16/58

TABLE IV

Hematology of Neonatal Pups

Group	Dam	No.	Time after birth blood taken.	RBC ($x10^6$)	WBC (x10)	RBC/WBC
B	H-97	1	20-45 minutes	4.26	3.10	1375
	7/4/58	2	20-45 minutes	4.17	3.45	1208
		3	20-45 minutes	4.60	3.00	1531
		4	20-45 minutes	5.18	3.35	1545
		5	20-45 minutes	4.32	3.50	1231
		6	20-45 minutes	4.42	3.25	1360
	H-92	1	12 hours	5.28	29.5	179
	12/14/58	2	12 hours	3.13	27.85	112
D	H-90	1	10 hours	3.555	21.85	162
	11/15/58	2	10 hours	3.945	23.60	167

TABLE V

Summary of New Dog Weights (Lbs.)

Ear Mark	February 24	March 3
	Males	
16	11.0	13.5
17	11.5	12.7
19	10.9	13.4
0	8.2	8.7
14	10.3	11.6
24	16.2	18.4
3	7.5	8.9
10	6.7	7.4
5	7.6	8.9
12	6.6	7.0
23	14.0	15.5
	Females	
15	8.9	10.8
18	6.1	7.7
2	11.8	14.8
8	7.5	8.2
6	4.7	5.3
20	10.4	11.5
21	10.0	11.2
1	10.6	13.6

CONTRACT RESEARCH PROGRESS REPORT

Department of the Army-Office of the Surgeon General

University of California
Department of Physiological Chemistry
Los Angeles 24, California

Contract No. DA-49-007-MD-579
Report No. 3
Period: September 15, 1958 - March 15, 1959

Official Investigators: Ralph W. McKee
Louis J. Zeldis

Collaborators: Margaret S. Dixon
Dean L. Moyer

Title of Contract: The Influence of Irradiated Lipids on the Incidence of Spontaneous Mammary Carcinoma and Hepatoma in Strain A/He and C_3H Mice.

SUMMARY

1. Three groups of C_3H and three groups of A/He mice have been on feeding studies for fifteen months to determine the effect of 5.58 megarads on bacon as the irradiation may influence spontaneous mammary and liver cancer.
2. The highest incidence of mammary tumor in C_3H mice is in the non-irradiated diet group, followed by the control and irradiated groups.
3. A/He mice have had a high incidence of a non-cancerous kidney disease.

This is not a final report. Conclusions stated are subject to change on the basis of additional evidence. Information contained herein is not to be reprinted or published without written permission from Research and Development Division, Office of the Surgeon General, Department of the Army, Washington 25, D.C.

McK-1

INTRODUCTION

This is the third progress report concerning the feeding of mice a diet containing irradiated and non-irradiated bacon lipids. The purpose of the investigation is to determine whether or not the incidence of spontaneous mammary carcinoma and hepatoma is altered. The work is being carried on in the departments of Physiological Chemistry and of Pathology, School of Medicine, University of California, Los Angeles 24, California.

MATERIALS AND METHODS

The feeding of C_3H and A/He mice a diet containing irradiated and non-irradiated bacon lipids has been in progress for fifteen months. The composition of the control, irradiated and non-irradiated bacon lipid diets was given in Progress Report 1, March 15, 1958. Table 1 gives average animal weights at different periods during the feeding program. The lipid diets at the beginning of the experiment contained 10% lipid. The per cent of lipid was increased to 15% after the experiment had been in progress 6 months and to 20% after nine months.

OBSERVATIONS ON BACON FAT STUDIES

Unsaturation of fatty acids and peroxide numbers have been determined on each can of bacon fat as described in our first Progress Report (March 15, 1958). The average peroxide number on the non-irradiated bacon fat has been 7.8 and on the irradiated bacon fat 12.1. The unsaturation of fatty acids was determined by the Wij's (iodine) procedure. The average values (expressed as milliliters of iodine absorbed per gram fat) for the non-irradiated fat has been 49.7 and for the irradiated 50.1.

The mice have been on the bacon fat diets for fifteen months. The first

C_3H mammary tumor was observed when the animal was six months old. The first A/He mammary tumor was observed when the animal was eleven and one-half months old. Tumor developments to March 1, 1959 are shown in Table 2. There appears to be no significant difference in tumor incidence between the diet groups. The incidence of more than one palpable tumor per animal is given in Table 3.

Table 4 gives the number of pulmonary metastases that have been grossly observed in mammary tumor bearing C_3H mice. The metastases that have been microscopically examined are bronchial adenomas.

Tumor tissue is weighed after a tumor animal is sacrificed. As indicated in Table 5 there is no significant difference in the average tumor weight by diet group.

Ten C_3H animals have died or been sacrificed for reasons other than mammary tumors, lymphoblastomas, or chronic salpingitis. Of the A/He deaths, a large percentage have been from causes other than tumor. During the last three months, as the animals have reached an advanced age (18-20 months) the number of A/He deaths has increased. Table 6 shows the number of deaths at intervals during the feeding program. The Histologic Studies section of this report will cover pathological findings to date on the A/He mice.

HISTOLOGIC STUDIES

C_3H Mice

The C_3H tumors that have been microscopically examined are adenocarcinomas of the mammary gland. The appearance of the tumors from the different diet groups has shown no significant difference. Grossly, all of the C_3H tumors appear to be adenocarcinomas, except the following.

Two animals, one in the control and one in the non-irradiated lipid diet had lymphoblastomas. A control animal had an osteo-sarcoma and an irradiated

diet animal had a fibrosarcoma. Mesenteric and ovarian cysts have been grossly noted in seven animals. Tissue sections have been examined in two animals, one in the non-irradiated and one in the irradiated diet group, revealing the cysts to be benign. Salpingitis has been grossly observed in uterine horns of eleven animals. One animal in each diet group showed gross evidence of pneumonia.

A/He Mice

As indicated in Table 2 a small percentage of A/He mice have had mammary tumors. Four tumors, one in both the control and irradiated fat groups and two in the non-irradiated fat group appear to be squamous papillomas of the vulva. Four tumors, three in the control and one in the non-irradiated fat groups are lymphoblastomas. There have been three tumors of the mediastinum, two in the non-irradiated fat group and one in the irradiated.

Lung nodules have been grossly observed in fifty-eight A/He animals. The nodules range in size from 1 to 4 mm in diameter. Initial microscopic examination has revealed adenocarcinoma in four of the animals. Lung tissue from several other animals has shown no sign of malignancy.

Kidney abnormalities have been grossly observed in 131 A/He mice; 30 in the control, 52 in the non-irradiated, and 49 in the irradiated. Initial microscopic examination has given diagnoses of focal pyelonephritis with calcification of convoluted tubules.

Twenty-nine A/He mice, eight in the control; nine in the non-irradiated and twelve in the irradiated, appear to have granulomatous abscess of the liver.

Rectal prolapse is observed in eleven animals; four in the control, six in the non-irradiated and one in the irradiated. Of three animals; two in the non-irradiated and one in the irradiated, microscopic examination confirms the gross diagnosis of intussusception with intestinal obstruction. McK-4

Gross observations on other A/He mice have included atelectatic and congested lungs, apparently enlarged thymus with proptoses and marked obesity with grossly fatty livers.

TABLE 1

Mouse Weight Data (Ave. weight in grams)

Months on Experiment	Control		Non-irradiated		Irradiated	
	C_3H	A/He	C_3H	A/He	C_3H	A/He
1	24.8	20.1	25.3	20.6	25.0	19.9
3	32.8	25.5	38.5	28.4	36.5	27.3
6*	35.9	26.9	43.3	29.8	41.0	28.5
9**	37.7	27.1	47.0	30.0	44.3	28.1
12	35.9	25.7	46.0	25.9	43.0	24.5
15	37.0	24.7	44.7	26.4	40.4	23.8

*Fat % increased to 15% when animals had been on experiment 6 months.

**Fat % increased to 20% when animals had been on experiment 9 months.

McK-6

TABLE 2

Summary of C_3H Tumor Mice

Diet	No. Animals at Beginning of Diet	No. Animals with Tumors	% Animals with Tumors	No. Tumor Animals Sacrificed & Died
Control	98	74	75.5	68
Non-irradiated bacon lipid	149	123	82.6	114
Irradiated bacon lipid	147	107	72.8	95

Summary of A/He Mammary Tumors

Diet	No. of Animals at Beginning of Diet	No. Animals with Mammary Tumors
Control	91	1
Non-irradiated bacon lipid	136	3
Irradiated bacon lipid	136	3

McK-7

TABLE 3

C_3H Animals with More than 1 Palpable Tumor

Diet	No. Animals with tumors	No. Animals with 2 or more tumors	% Animals with 2 or more tumors
Control	74	28	37.8
Non-irradiated bacon lipid	123	55	44.7
Irradiated bacon lipid	107	40	37.4

TABLE 4

C_3H Animals with Metastases

Diet	No. Animals with tumors	No. Animals with Metastases	% Animals with Metastases
Control	74	14	18.9
Non-irradiated bacon lipid	123	32	26.0
Irradiated bacon lipid	107	29	27.1

TABLE 5

Weights of C_3H Tumors

Diet	Range of Tumor Weight in Grams	Average Tumor Weight in Grams	Average Tumor Age When Animal Sacrificed
Control	2.6 to 25.4	11.38	56
Non-irradiated bacon lipid	1.94 to 31.9	11.49	55
Irradiated bacon lipid	.90 to 24.3	11.14	53

TABLE 6

A/He Deaths

Diet	Control	Non-irradiated Bacon Fat	Irradiated Bacon Fat
Number of animals at beginning of bacon fat diet	91	136	136
Number of deaths by weeks on diet			
1-22	2	4	2
23-45	8	32	23
46-52	14	16	25
53-59	14	16	25
60-66	13	27	28

SIX MONTHS REPORT FOR THE PERIOD ENDING MARCH 15, 1959

TITLE OF PROJECT: EFFECT OF IONIZED RADIATION ON THE NUTRITIVE VALUE OF FOOD.

REPORT BY: CLIVE M. MCCAY, STOCKING HALL, CORNELL UNIVERSITY, ITHACA, NEW YORK.

INTRODUCTION: SUPPLIES OF FEEDSTUFFS HAVE ARRIVED IN GOOD CONDITION AND IN ADEQUATE AMOUNTS EXCEPT FOR POTATOES. ONE SUPPLY OF THESE SEEMED TO HAVE SPROUTED AND ROTTED BEFORE SHIPMENT. THE NEW SUPPLY FROM THE CROP OF 1958 CAME THROUGH IN GOOD CONDITION. WE HAVE FOLLOWED THE PLAN OF COOKING AND FREEZING THE SUPPLY OF NON-RADIATED POTATOES WHEN THEY STARTED TO SPROUT BADLY. AT A SLIGHTLY LATER DATE WE HAVE ALSO COOKED AND STORED THE RADIATED.

BEEF AND PORK: ALL BEAGLES UPON THESE EXPERIMENTS WERE TRANSFERRED TO THE VETERINARY PATHOLOGY DIVISION IN MID SUMMER 1958. ABOUT TWO THIRDS OF THESE HAVE HAD SLIDES COMPLETED.

NO DEVIATION FROM THE NORMAL HAS BEEN FOUND THUS FAR IN THESE STUDIES EXCEPT THAT THERE WAS SIGNIFICANT FAILURE IN REPRODUCTION OF FEMALE BEAGLES FED THE RADIATED BEEF. THESE WERE FED VITAMINS A AND E SEPARATELY.

CORN, CHICKEN AND TUNA FISH: THESE BEAGLES ARE NOW ADULTS AND WILL COMPLETE TWO YEARS UPON THE DIETS IN MID SUMMER, 1959. IT IS PLANNED TO KILL THEM FOR POST MORTEM STUDY AT THAT TIME. INITIAL REPRODUCTION EXPERIENCE WITH THESE BEAGLES INDICATES THAT THOSE UPON THE CHICKEN DIETS HAVE DONE VERY WELL WHILE THE OTHERS UPON TUNA AND CORN HAVE GIVEN POOR REPRODUCTION THUS FAR. THESE RESULTS DO NOT SEEM RELATED TO THE RADIATION OF THE FOOD BUT TO OTHER PROPERTIES.

POTATO (7.5 AND 15 THOUSAND RADS): FOURTEEN BEAGLES WERE STARTED AT THE TIME OF WEANING UPON THESE POTATO DIETS GIVING ONE THIRD OF THE DRY MATTER IN THE FORM OF BOILED POTATOES. THESE BEAGLES ARE NOW REACHING ADULT SIZE AND BODY WEIGHTS OF 11 TO 15 POUNDS. THEY HAVE GROWN WELL AND NOTHING UNUSUAL HAS BEEN OBSERVED. STARTED 7/21/58.

REPORTS: DETAILED REPORTS FOR ALL BEAGLES THAT HAVE BEEN KILLED AND STUDIED FROM THE PORK AND BEEF DIETS ARE IN PREPARATION. THESE WILL INCLUDE GROWTH CURVES, HEMATOLOGY AND X-RAY STUDIES OF BONES. THEY WILL HAVE USE CHIEFLY AS REFERENCE TO THE PERFORMANCE OF NORMAL, HEALTHY BEAGLES.

McK-1

15 December 1959

MEDEC-ZO

SUBJECT: Final Report on the Gamma-Ray Activity of Quartermaster Bacon Samples Submitted to Walter Reed Army Institute of Research During August, September, and October, 1959

TO: U. S. Army Medical Research and Nutrition Laboratory
Fitzsimmons Army Hospital
Denver, Colorado
ATTN: Colonel I. E. Plough

Transmitted herewith find Final Report on bacon samples submitted to Walter Reed Army Institute of Research during August, September, and October, 1959. These samples were furnished by the Food Irradiatio Preservation Division, Quartermaster Food and Container Institute, Chicago, Illinois.

1 Incl
15 copies

KENT T. WOODWARD
Major, MC
Chief, Department of Biophysics

FINAL REPORT ON THE GAMMA-RAY ACTIVITY OF QUARTERMASTER BACON SAMPLES SUBMITTED TO WALTER REED ARMY INSTITUTE OF RESEARCH DURING AUGUST, SEPTEMBER, AND OCTOBER, 1959

1. Bacon samples received from QMC during August, September, and October, 1959 were counted in 180 pound lots (after removal from No. 10 can) in the Walter Reed Human Counter before (ASSAY I) and after (ASSAY II) irradiation. Samples irradiated at SRIF were double sealed in plastic packs and assays were done after removal of the outer pack. The human counter is a 4π liquid scintillation detector and is operated with two channel analysis, maximizing the efficiency of detecting cesium-137 and potassium-40. The two ranges of gamma energy discrimination are rather wide, about 0.3 to 0.8 mev and 0.8 to 1.6 mev. Over a sample weight range of 40 to 280 pounds, mass absorption corrections are applied and calibrations for Cs-137 and K-40 are within ± 5 percent. Sample count rates are converted to disintegrations per second assuming that the observed count rates are due to Cs-137 and K-40. Selected bacon samples were also analyzed for gamma-ray activity by the 8 x 4 inch sodium iodide crystal and multi-channel spectrometer.

2. Eight control samples (Lots 1, 2, 7, 8, 13, 14, 19, and 20) were counted on two occassions and the combined results are 0.39 ± 0.1 dps/lb for Cs-137 and 1.29 ± 0.12 dps/lb for K-40. The deviations from the mean are rather large (± 26 percent for Cs-137 and ± 9.3 percent for K-40). However the accuracy of the determinations vary by about ± 12 percent and ± 6 percent respectively at these levels of Cs-137 and K-40 content; biological variation between meat samples accounts for the remainder.

3. Inclosure I lists the bacon assays before and after irradiation at MTR, DPG, and SRIF. None of the bacon samples irradiated at DPG showed a significant increase in gamma activity. MTR sample, Lots 3 and 4, showed a significant increase (greater than 3 sigma of the control mean) in gamma activity in both energy ranges. Lot 6 showed a significant increase in gamma activity only in the 0.8 - 1.6 mev energy range. It is to be noted that empty No. 10 cans (approximately 27 pounds) also showed significant increases in gamma activity after exposure at MTR and SRIF. Bacon samples irradiated at SRIF were assayed on 26 October 1959, some 3 days after exposure. All irradiated bacon samples contained about 11-12 muc of Na-24 gamma-ray activity at this time (Inclosure II - typical gamma-ray spectrum). Since the 1.3 mev gamma-ray from Na-24 was not seen as a discrete photopeak from the 1.46 mev gamma-ray of K-40, the half-life of the 2.7 mev activity (Sample 6-01805 #17) was also determined to be certain of the presence of Na-24. This was found to be 14 hours.

4. Inclosure III shows the gamma-ray spectrum (0 to 3 mev) of an unirradiated control sample of bacon (Lot 19 - Number 6-01807). The two most prominent peaks correspond to the photon energies of cesium-137 and potassium-40. The 1.1 mev photopeak may well be Zn-65 from fallout as previously noted in lean beef and calves liver by M. A. Van dilla of the Los Alamos Group. Also Murthy et al report the presence of Zn-65 in milk, seafood, etc. (Science, 130:1255, 6 November 1959).

3 Incl
a/s

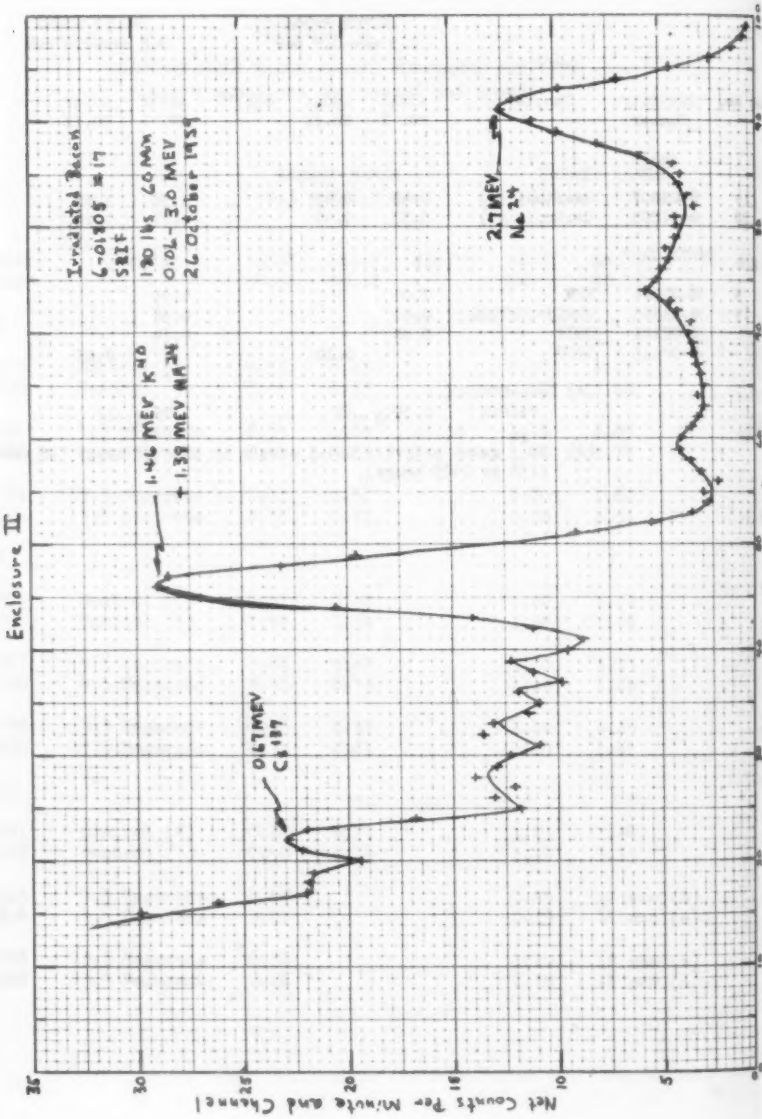
ENCLOSURE I

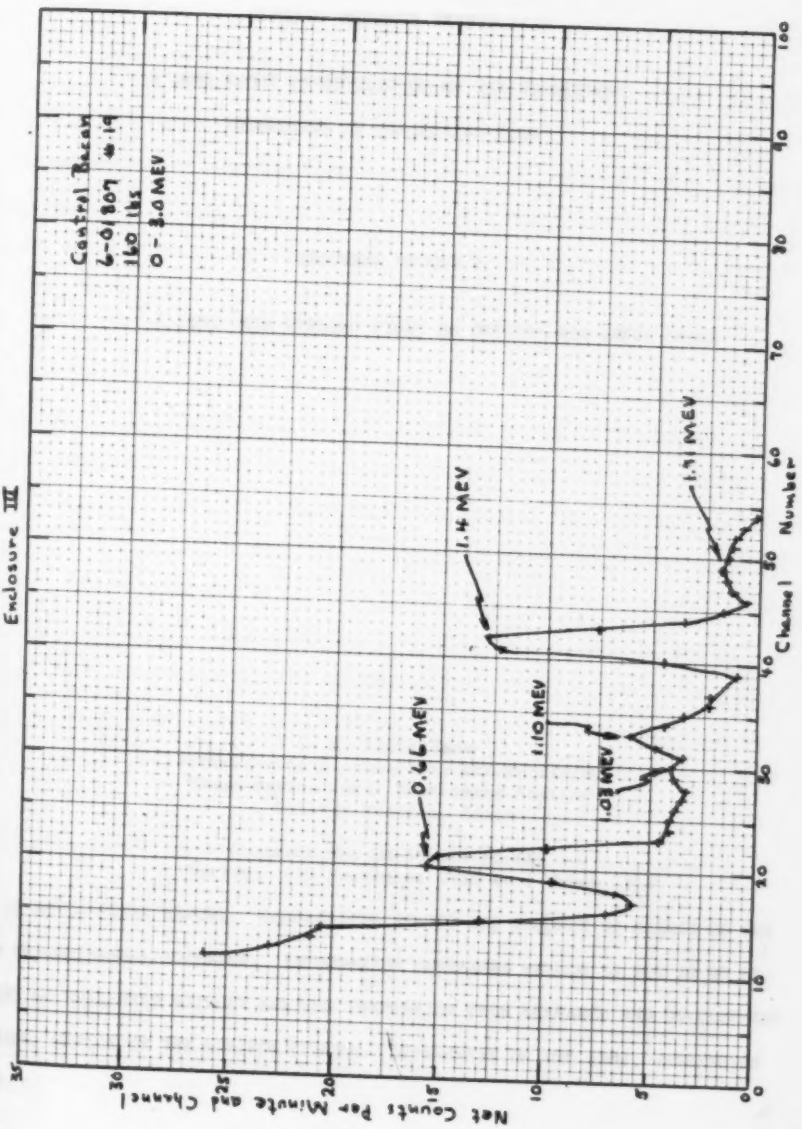
QUARTERMASTER BACON ASSAYS FOR GAMMA ACTIVITY
(disintegrations per second and pound)

Lot No.	Identity Number	Sample	ENERGY RANGE 0.3 mev-0.8 mev ASSAY NO. I	ASSAY NO.II	$d(n)^{-\frac{1}{2}}$	ENERGY RANGE 0.8 mev-1.6 mev ASSAY NO. I	ASSAY NO.II	$d(n)^{-\frac{1}{2}}$
	MTR							
1	6-01789	Control (*)	0.32	0.23		1.37	1.28	
2	6-01790	Control (*)	0.39	0.37		1.40	1.63	
3	6-01791	4.5 Megarads	0.54	1.04	+6.38	1.19	2.85	+9.2
4	6-01792	4.5 Megarads	0.42	0.73		1.20	1.79	
5	6-01793	13.5 Megarads	0.43	0.57		1.00	1.62	
6	6-01794	13.5 Megarads	0.45	0.27		0.98	2.51	+7.2
	DPG							
7	6-01795	Control (*)	0.47	0.45		1.22	1.22	
8	6-01796	Control (*)	0.49	0.54		1.36	1.39	
9	6-01797	4.5 Megarads	0.45	0.47		1.30	1.23	
10	6-01798	4.5 Megarads	0.40	0.53		1.10	1.28	
11	6-01799	13.5 Megarads	0.46	0.37		1.28	1.25	
12	6-01800	13.5 Megarads	0.38	0.61		1.09	1.41	
	SRIF							
13	6-01801	Control (*)	0.27	0.23		1.23	1.24	
14	6-01802	Control (*)	0.40	0.29		1.14	1.15	
15	6-01803	4.5 Megarads	0.68			0.89	12 muc (a)	
16	6-01804	4.5 Megarads	0.21			0.19	11 muc (a)	
17	6-01805	13.5 Megarads	0.38			1.10	12 muc (a)	
18	6-01806	13.5 Megarads	0.26			1.18	12 muc (a)	

Lot No.	Identity Number	Sample	ENERGY RANGE 0.3 mev-0.8 mev ASSAY NO. I	ASSAY NO.II	$d(n)^{-½}$	ENERGY RANGE 0.8 mev-1.6 mev ASSAY NO. I	ASSAY NO.II	$d(n)^{-½}$
	WRAIR							
19	6-01807	Resident (*)	0.41	0.43		1.36	1.38	
20	6-01808	Controls (*)	0.52	0.40		1.17	1.20	
	EMPTY CANS							
3	8-01864	MTR	2.04			4.35		
19	8-01865	WRAIR-CONTROL	0.42			0.36		
	8-02101	SRIF	0.08			0.74		
	8-02113	SRIF		0.10			2.87	
		(*) Mean CONTROL VALUES	0.39 ± .10			1.29 ± .12		

(A) Na^{24} gamma activity total sample at time of assay (26 October 59, 1238 to 1429 hours).


Enclosure II
Irradiated Bacon
6-01905 #17
SRIF
180 lbs. 60 Min
0.04-3.0 MEV
26 October 1959
1.46 MEV K40
+1.38 MEV Na24
2.7 MEV
Na24
0.67 MEV
Cs137
Net Counts Per Minute and Channel
35
30
25
20
15
10
5
0
720


Enclosure III
Control Bacon
6-01807 # 19
160 lbs
0 - 3.0 MEV
0.66 MEV
1.03 MEV
1.10 MEV
1.4 MEV
1.7 MEV
Net Counts Per Minute and Channel
Channel Number

GENERAL PROGRESS REPORT XIII

A LONG RANGE INVESTIGATION OF THE NUTRITION PROPERTIES OF IRRADIATED FOOD

PROGRESS REPORT V

A LONG TERM FEEDING STUDY ON CHICKEN AND GREEN BEANS

BY

L. R. Richardson
Professor of Biochemistry and Nutrition
Texas Agricultural Experiment Station
College Station, Texas

Contract No. DA-49-077-MD-582
Period: 15 September 1958 to 1 March 1959

THIS IS NOT A FINAL REPORT. CONCLUSIONS STATED ARE SUBJECT TO CHANGE ON THE BASIS OF ADDITIONAL EVIDENCE. INFORMATION CONTAINED HEREIN IS NOT TO BE REPRINTED OR PUBLISHED WITHOUT WRITTEN PERMISSION FROM RESEARCH AND DEVELOPMENT DIVISION, OFFICE OF THE SURGEON GENERAL, DEPARTMENT OF THE ARMY, WASHINGTON 25, D. C.

R.1

ABSTRACT

Observations on Rats Receiving Irradiated Green Bean and Chicken Diet.

Growth, reproduction, weaning weight of young, mortality rate, weights of organs, and hematological values in rats receiving diets containing various combinations of green beans and chicken that were treated with 0, X and 2X doses of gamma radiations show that the irradiated foods are not injurious. These observations show also that the nutritive value of irradiated food is essentially equal to that of the control foods.

Congential Blindness.

Congential blindness in the offspring from females receiving an irradiated and control synthetic diet was essentially the same in the third trial. In the first and second trial the incidence of blindness was higher in young from females receiving the irradiated diet.

Hemorrhagic Syndrome.

Strain of Rats- Approximately 150 Texas A & M strain rats received irradiated beef without developing the typical hemorrhagic syndrome. Recently, Holtzman strain rats were used and four animals have developed hemorrhages in the thoracic cavity. Plasma prothrombin times were prolonged in rats receiving irradiated beef in both strains.

Extraction of Dried Beef- Dried irradiated beef was extracted with chloroform and ethyl ether. Rats receiving the chloroform or ether residue developed long plasma prothrombin times while those receiving the chloroform and ether soluble fractions had normal prothrombin times.

Combination of Ether Extract and Residue from Control and Irradiated Beef. When control residue was combined with ether soluble fraction from irradiated

beef, prothrombin times were longer than when irradiated residue was combined with control ether soluble fraction. Interpretation of these results is not clear from this preliminary test.

A Long Term Feeding Study With Chicken and Green Beans

Growth and Food Consumption in Parent, F_1 and F_2 Generations.

Both females, Figure 1, and males, Figure 2, in F_1 and F_2 generations were much smaller at 12 weeks than those in the parent generation. There was a wide variation between groups, but there was no indication that the variation was due to a specific treatment of the food. The slow rate of growth of both males and females at 12 weeks was so characteristic that it became of interest to determine whether the animals in the F_1 and F_2 generations eventually attained the same size as those in the parent generation. The average weights of the males, Figure 3, at 24 weeks show that the males in F_1 and F_2 generations were as heavy at 24 weeks as those in the parent generation. The weights for the females were not plotted at 24 weeks because they were in reproduction and the average weight at this time may be complicated by pregnancy. The mature females weighed approximately the same in all groups. Food consumption of the parent generation for two weeks when the animals were 18 months old is given in Table 1. The difference in food consumption between diets was not associated with treatment of either food.

Young Observed and Weaned in Three Generations.

The number and the percent of young weaned by females in the parent, F_1 and F_2 generations receiving green bean and chicken diets are summarized in Table 2. Data for the first and second litter of each female are combined. The percent of young weaned in the various groups ranged from 12 to 98. In some cases the percent weaned was higher when both foods in the diet were irradiated than it was in the control group.

In view of this observation, it is very improbable that the variation between the groups receiving the various diets was due to irradiated food.

TABLE 1

Average Gain in Weight in Rats in Parent Generation and Food Consumption Per Week[1] When Animals Were 18 Months Old.

Group	Diet GB	Diet CK	No.	Sex	Average Gain[2] grams	Food Consumption gm/rt/wk.
1	0	0	13	Male	403	367
			26	Female	270	327
2	0	X	2	Male	315	319
			4	Female	244	299
3	0	2X	3	Male	494	454
			8	Female	255	322
4	X	0	3	Male	276	526
			8	Female	272	308
5	X	X	1	Male	260	318
			10	Female	263	279
6	X	2X	1	Male	385	376
			7	Female	248	271
7	2X	0	4	Male	363	329
			9	Female	247	288
8	2X	X	3	Male	260	287
			9	Female	300	359
9	2X	2X	4	Male	380	360
			2	Female	252	265

[1] Food record was kept for 14 days when the animals were 18 months old.

[2] Gain = Initial minus weight at 18 months.

R-8

TABLE 2

Number of Young Observed and Weaned in Parent, F_1 and F_2 Generation Females Receiving Green Beans(GB) and Chicken(CK) Diets.

DIET		PARENT			F-1			F-2		
GB	CK	Obs.	Weaned		Obs.	Weaned		Obs.	Weaned	
		No.	No.	%	No.	No.	%	No.	No.	%
0	0	207	88	42.5	142	102	71.8	180	120	66.7
0	X	74	43	58.1	60	39	65.0	41	27	65.8
0	2X	91	55	60.4	43	35	81.3	90	88	97.7
X	0	66	17	25.7	48	35	72.9	68	60	88.2
X	X	77	31	40.2	74	61	82.4	38	27	71.0
X	2X	51	6	11.8	51	35	68.6	60	28	46.7
2X	0	69	14	20.3	8	6	75.0	71	48	67.6
2X	X	78	29	37.1	86	51	59.3	84	78	92.8
2X	2X	78	38	49.7	55	27	49.1	70	18	25.7

[1] Young in first and second litters combined.
Original number of females receiving GBO and CKO = 18. All other groups contained 6 females.

0 = Non-irradiated
X = 2.79×10^6 rad
2X = 5.58×10^6 rad

R-9

Fertility

The percent of females that were fertile and the percent of fertile females that produced two litters are summarized in Table 3. Similar data for males are summarized in Table 4. Both males and females were fertile and produced more than one litter of young. Rats receiving green beans irradiated at 2 x level and control chicken in the F_1 generation had the poorest fertility record. Only two females and two males in this group were fertile and no young were weaned in the second litters by either female.

Since all the females and males in each of the three generations that received the diet containing GB2X + CKX were fertile, it seems very probable that the low fertile rats in the group receiving GB2X + CK0 were not due to the irradiated food.

TABLE 3

Fertility of Female Rats Receiving Green Beans (GB) and Chicken (CK) in Parent, F_1 and F_2 Generation.

DIET		FERTILE FEMALES - %			PRODUCING TWO LITTERS - %		
GB	CK	P	F-1	F-2	P	F-1	F-2
		%	%	%	%	%	%
0	0	100	89	78	94	100	92.8
0	X	100	100	67	100	100	100
0	2X	100	100	100	100	83	100
X	0	100	83	100	100	100	100
X	X	100	100	67	100	67	50
X	2X	100	67	100	83	100	100
2X	0	83	33	100	80	0	67
2X	X	100	100	100	100	100	100
2X	2X	100	83	100	100	100	83

Original number receiving control diet was 18 females. Original number receiving all other diets was 6 females in each group.

TABLE 4

Fertility of Male Rats Receiving Green Bean(GB) and Chicken(CK) Diet in Parent, F_1 and F_2 Generations.

DIET		FERTILE - %			LITTERS SIRED PER FERTILE MALE - No.		
GB	CK	P	F-1	F-2	P	F-1	F-2
0	0	94	67	88	2.8	2.7	1.4
0	X	100	100	67	2.5	1.8	2.2
0	2X	83	100	100	3.2	2.0	2.0
X	0	100	100	100	2.2	1.9	2.0
X	X	100	67	50	2.8	2.7	1.6
X	2X	67	100	100	3.2	1.7	1.7
2X	0	100	33	83	2.7	1.0	1.6
2X	X	100	100	100	2.3	2.3	2.2
2X	2X	100	100	83	2.2	1.7	1.6

Deposition of Rats in the Parent Generation.

The deposition of the animals in the parent generation receiving chicken and green bean diets on February 16, 1959 is summarized in Table 5. Many of the animals in the colony died very suddenly during the last of January and first of February. Animals which appeared normal one afternoon were found dead the next morning.

This high mortality was distributed throughout the animals and occurred in other tests as well as those on irradiated foods. The disease responsible for the high mortality was thought to be an accute respiratory disease and was worse in the old animals.

The mortality rate was no greater in the rats receiving irradiated foods than it was in those receiving the control foods.

Average Weight of Organs in Parent Generation at Time the Animals Were Sacrificed

The average weight of organs of rats in the parent generation which were sacrificed are given in Table 6. The weight of organs for individual animals in the parent generation will be given in the autopsy report, and the average

TABLE 5

Final Deposition of Parent Generation Rats Receiving Green Bean and Chicken Diets.

DIET		SEX	DIED		SACRIFICED		LIVING
GB	CK		No.	Avr.Age-Days	No.	Avr.Age-Days	Feb. 1959-No.
0	0	Male	7	515	23	532	0
		Female	12	671	10	605	8
0	X	Male	2	649	8	440	0
		Female	4	630	6	467	0
0	2X	Male	2	668	8	476	0
		Female	5	568	5	677	0
X	0	Male	3	523	7	531	0
		Female	4	691	6	580	8
X	X	Male	5	497	5	384	0
		Female	5	695	4	632	1
X	2X	Male	6	423	4	480	0
		Female	4	588	4	607	2
2X	0	Male	5	485	5	531	0
		Female	5	672	4	674	1
2X	X	Male	4	469	6	495	0
		Female	5	699	3	635	2
2X	2X	Male	5	501	5	550	0
		Female	1	466	7	472	2

R-12

values for the animals in F_1 generation were given in Table 7, general progress report No. 12. Values for F_2 generation are incomplete.

Weights of heart, spleen, kidneys, and testes are within the range reported as normal for rats of similar age and weight. The lungs were heavier and liver lighter in weight than that report for normal rats. None of these differences can be attributed to the irradiated food, because the same differences were present in the control group.

TABLE 6

Average Weight of Organs

DIET		SEX	HEART	LUNGS	LIVER	SPLEEN	KIDNEYS	TESTIS
GB	CK						R / L	R / L
0	0	Male	1.29	4.95	10.23	.67	3.26	2.21
		Female	1.07	4.06	6.73	.47	1.98	
0	X	Male	1.38	5.78	10.09	.53	3.09	2.54
		Female	.98	4.28	8.16	.51	1.85	
0	2X	Male	1.17	4.41	8.82	.51	2.68	2.12
		Female	1.07	4.77	7.65	.42	2.36	
X	0	Male	1.61	4.78	10.43	.72	3.51	2.19
		Female	.99	4.12	6.99	.62	2.01	
X	X	Male	1.28	4.57	10.11	.65	3.00	2.75
		Female	.96	2.68	6.47	.38	1.97	
X	2X	Male	1.21	4.61	10.70	.54	2.75	2.97
		Female	1.07	5.14	8.13	.38	1.84	
2X	0	Male	1.17	6.81	9.68	.65	2.98	2.10
		Female	.99	4.79	6.33	.36	2.14	
2X	X	Male	1.26	4.92	9.79	.42	2.92	2.35
		Female	1.12	3.85	9.51	1.12	2.57	
2X	2X	Male	1.38	4.32	10.48	.62	2.69	2.11
		Female	.93	4.27	6.65	.58	1.93	

Weight of Young.

The average weaning weight of the young born to females in the Parent, F_1 and F_2 generations are given in Table 7. There is no consistent differences in the weaning weights of the young associated with the irradiation of either the green beans or the chicken.

TABLE 7

Average Weight of Young at 21 Days

DIET		P	F-1	F-2
GB	CK			
0	0	36	38	34
0	X	36	39	39
0	2X	29	36	34
X	0	35	37	38
X	X	32	35	34
X	2X	31	37	29
2X	0	31	40	30
2X	X	33	33	34
2X	2X	33	35	31

Hematological Studies.

The average hematological values of rats receiving green bean and chicken diets, when started on test and at 6 and 12 months are given in Table 8. Similar values when the rats were 12 and 18 months and when sacrificed over 18 months old are given in Table 9. Values for F_1 generation animals were given in Table 10 Report No. 12, and those for weanling young from F_2 generation females are given in Table 10.

The values for all animals under 18 months old were within normal range. When the animals were 18 months and older, there was a decrease in the proportion of lymphocytes and an increase in polymorphoneuclear Neutrophils. This change was associated with age of the animal rather than the treatment of the

food.

TABLE 8

Average Hematological Values of Rats in Parent Generation Receiving Green Bean (GB) and Chicken (CK) Diets. Blood Analyzed at Approximately 0, 6 and 12 Months of Age.

Diet		Age		AVERAGE HEMATOLOGICAL VALUES							
				Hbg	Hem	WBC	Differential				
GB	CK	Months	Sex		%		Lym	Mon	Eos	PMN	Bas
0	0	0	Male	12.4	37	8.0	80	0.0	0.0	20	0.0
		6		13.9	44	10.9	87	3.0	0.0	10	0.0
		12		13.0	48	10.8	75	3.5	4.5	15	2.0
		0	Female	14.4	35	8.2	76	0.3	1.0	23	0.0
		6		14.4	37	10.4	78	3.3	1.0	16	0.0
		12		19.7	45	9.9	79	4.3	1.7	13	1.7
0	2X	0	Male	12.3	33	8.6	79	1.0	7.0	19	0.0
		6		15.1	46	10.7	84	3.3	1.0	12	0.0
		12		16.7	46	12.0	74	3.0	1.0	20	1.3
		0	Female	12.9	33	8.6	81	1.0	0.3	18	0.0
		6		14.7	37	10.7	85	3.0	0.3	12	0.0
		12		16.4	45	12.0	85	3.0	0.7	10	0.7
X	0	0	Male	14.7	39	5.6	86	1.0	0.3	13	0.0
		6		16.0	42	12.6	86	3.7	0.0	11	0.0
		12		16.4	52	9.3	84	2.0	0.0	13	1.0
		0	Female	15.2	45	9.1	85	0.0	0.7	14	0.0
		6		14.5	38	10.9	82	1.7	0.7	15	0.0
		12		16.6	41	9.5	84	2.0	0.0	14	0.3
2X	2X	0	Male	14.0	47	13.3	79	1.7	0.3	20	0.0
		6		15.5	42	11.7	89	1.7	0.0	10	0.0
		12		16.5	49	12.1	86	4.0	1.0	9	0.0
		0	Female	14.4	45	9.8	83	0.7	0.0	17	0.0
		6		15.6	40	10.8	88	2.0	0.7	12	0.0
		12		16.5	45	12.4	80	2.0	1.0	17	0.3

See legend

A-15

Average Hematological Values of Parent Generation Rats Receiving Green Bean (GB) And Chicken (CK) Diets. Blood Analyzed at Approximately 12, 18 Months and When Animals Over 18 Months Old Were Sacrificed.

Diet		Age			AVERAGE HEMATOLOGICAL VALUES							
								Differential - %				
GB	CK	Months	Sex	Wt.	Hbg	Hem %	WBC	Lym	Mon	Eos	PMN	Bas
0	0	12	M	496	13.0	47	10.9	80	5.0	0.2	14	1.8
			F	297	13.6	47	10.0	80	4.7	0.8	13	2.0
		18	M	449	16.3	50	16.8	58	1.0	1.3	40	0.0
			F	310	16.7	48	10.9	69	0.6	0.8	29	0.2
		over 18	M	313	18.9	59	15.8	58	0.5	0.3	41	0.0
0	X	12	M	417	16.3	48	11.0	87	1.4	0.4	11	0.2
			F	282	15.9	47	11.2	88	2.2	0.0	9.3	0.2
		18	M	375	17.7	56	10.8	77	0.7	1.0	21	0.0
			F	263	16.7	50	13.9	77	0.8	0.8	22	0.0
		over 18	M	294	19.7	60	12.5	46	0.0	0.0	55	0.0
			F	175	19.0	48	13.6	73	0.0	0.0	27	0.0
0	2X	12	M	398	15.8	48	11.1	78	3.7	1.7	16	0.7
			F	315	15.5	45	9.8	86	2.7	0.5	10	0.5
		18	M	386	16.8	53	11.6	77	1.1	0.9	20	0.4
			F	287	16.7	49	12.2	73	1.1	1.1	25	0.1
		over 18	M	450	19.0	61	12.6	64	0.0	1.5	37	0.0
			F	315	19.0	52		78	0.0	1.0	21	0.0
X	0	12	M	465	15.3	47	11.9	84	1.7	1.3	13	0.2
			F	345	15.2	46	11.0	84	2.3	0.0	12	1.3
		18	M	336	17.4	50	17.9	57	0.7	0.3	41	0.3
			F	312	17.3	44	15.4	72	0.5	0.8	27	0.3
		over 18	F	285	13.5	40	21.1	60	3.0	1.0	35	1.0

TABLE 9 CON'T.

Diet		Age			AVERAGE HEMATOLOGICAL VALUES							
								Differential - %				
GB	CK	Months	Sex	Wt.	Hbg	Hem %	WBC	Lym	Mon	Eos	PMN	Bas
X	X	12	M	413	16.2	47	9.3	91	1.2	0.0	7	0.3
			F	330	16.2	47	9.4	90	1.2	0.2	8	0.3
		18	M	346	18.1	54	10.1	74	2.0	0.7	22	1.0
			F	293	17.0	50	14.2	71	1.0	0.5	28	0.0
X	2X	12	M	413	16.8	50	10.4	89	0.3	0.7	10	0.0
			F	325	16.6	49	10.8	89	1.8	1.2	8	0.2
X	2X	18	M	385	16.5	58	9.4	88	0.5	3.0	9	0.0
			F	290	16.9	48	13.6	69	0.2	0.8	30	0.2
		over 18	M	420	18.2	48	12.3	75	2.0	1.0	12	0.0
			F	306	16.2	44	15.5	44	0.0	0.0	56	0.0
2X	0	12	M	488	16.6	50	11.0	83	2.0	0.7	13	1.0
			F	304	16.5	47	10.4	82	2.3	0.2	15	0.7
		18	M	378	16.9	53	12.6	70	1.3	0.3	29	0.0
			F	274	16.9	49	11.1	64	0.9	0.4	34	0.3
		over 18	M	262	18.8	53	12.4	62	3.0	0.0	35	0.0
			F	238	17.5	46	9.3	55	1.3	0.0	33	0.3
2X	X	12	M	459	16.5	51	10.6	89	1.4	0.4	9	0.2
			F	325	15.5	45	10.1	88	1.0	0.5	10	0.0
		18	M	320	16.2	49	14.1	66	0.1	0.7	33	0.0
			F	321	16.8	47	9.0	65	0.2	1.3	34	0.0
		over 18	M	314	16.7	56	18.2	39	1.0	0.0	60	0.0
2X	2X	12	M	455	15.8	49	12.1	88	2.5	0.7	9	0.2
			F	243	16.5	48	12.5	84	1.5	8.0	13	0.3
		18	M	363	16.8	54	12.6	77	1.2	1.0	21	0.0
			F	249	16.0	47	10.6	78	1.7	0.9	18	0.7
		over 18	M	398	15.6	50	19.1	43	1.5	0.0	56	0.0
			F	211	16.9	48	19.5	59	1.0	0.0	40	0.0

See legend

TABLE 10

Summary of Hematological Values of Weanling Young Born to F_2 Generation Females.

Diet				AVERAGE		AVERAGE HEMATOLOGICAL VALUES							
									DIFFERENTIAL				
CS	CX	No.	Sex	Age (Days)	Wt.	Hbg	Hem %	WBC	Lym	Mon	Eos	PMN	Bas
0	0	8	M	29.6	53	12.9	39	9.7	75	1.1	0.1	24	0.3
		6	F	30.6	52	13.0	41	7.0	78	0.9	0.1	21	0.1
0	X	1	M	24.0	60	13.0	71	17.6	84	0.0	0.0	16	0.0
		2	F	22.5	53	12.0	41	12.2	79	0.5	0.0	20	0.0
0	2X	6	M	26.8	32	12.4	31	9.1	89	1.2	0.3	10	0.2
		6	F	26.8	29	11.8	33	9.6	91	0.8	0.7	8	0.0
X	0	6	M	34.0	83	11.5	42	15.3	79	0.2	0.0	21	0.0
		6	F	34.0	72	12.1	40	14.2	85	0.0	0.3	14	0.2
X	X	1	M	28.0	40	11.4	35	13.4	91	3.0	0.0	6	0.0
		1	F	28.0	36	10.8	28	13.4	89	3.0	0.0	14	0.2
X	2X	5	M	33.0	64	13.9	39	9.8	82	0.8	0.0	17	0.0
		5	F	33.0	62	13.7	40	8.6	79	1.2	0.0	20	0.0
2X	0	1	M	31.0	55	10.7	33	13.3	88	0.0	0.0	12	0.0
		2	F	36.5	76	13.3	38	14.6	82	0.3	0.0	18	0.0
2X	X	3	M	33.0	68	11.7	35	6.6	80	1.7	0.0	19	0.0
		4	F	32.5	62	12.5	38	8.5	82	0.3	0.0	18	0.0
2X	2X	3	M	26.0	37	11.2	35	9.9	86	0.7	0.3	13	0.0
		3	F	26.0	35	11.4	34	9.5	85	0.3	0.3	14	0.0

See legend

R-18

LEGEND TO HEADING IN TABLES 8, 9, and 10

hbg = grams hemoglobin per 100 ml of blood

Hem = cell volume (hematocrit %)

WBC = total leucocyte count, value multiplied by 10^{-3}

DIFFERENTIAL %

Lym = Lympocytes

Mon = Monocytes

Eos = Eosinophils

PMN = Polymorphonecular Neutrophils

Bas = Basophils

GB = Green Beans

CK = Chicken

0 = Non-irradiated

X = 2.79×10^6 rads

2X = 5.58×10^6 rads

Congential Blindness

The incidence of congential blindness was determined in the offspring from females that received irradiated and control synthetic diets in three separate trials. These data are summarized in Table 11. The incidence of blindness was approximately three times higher in the first trial and two times higher in the second trial in the young from females receiving the irradiated diet than it was in the young from those receiving the control diet.

So far, in the third trial the incidence has been slightly lower in the irradiated than in the control group and the overall incidence of blindness was much lower in the second and third trials than it was in the first.

Congential blindness has been reported previously in infant rats, and it appears very probable that the difference between the irradiated and control group is not due to the effect of irradiation on the diet.

TABLE 11

Congential Blindness

	EXP. No.	LITTERS	BORN	OBSERVED	WEANED		BLIND	
					#	%	#	%
Original	Irradiated		3467	2993	2567	84.7	134	4.48
	Control		3290	2923	2667	90.9	48	1.44
1st Repeat	Irradiated	242	1521	1398	1109	72.9	11	.72
	Control	201	1251	1082	802	64.1	5	.40
2nd Repeat	Irradiated	96	661	587	512	77.4	5	.76
	Control	91	678	593	525	77.4	6	.88
	(In Progress)							

R-20

R-19

Hemorrhagic Syndrome

Tests carried out to determine the mechanism of the action of irradiated beef in producing the hemorrhagic syndrome in male rats has been directed primarily to locate and concentrate the active agent from the irradiated beef.

Dried Beef.

In order to have dry material to use in extraction procedures, irradiated and control beef were cooked in an oven for two hours at 350°F. The cooked beef was then spread out in 36" x 17" enamel trays about one inch deep and dried in a steam heated air circulating drier. A thermometer in the beef did not exceed 60°C any time during the drying process.

The prothrombin times of blood plasma and the weights of individual rats receiving irradiated and non-irradiated dried beef at 6 and 12 weeks are summarized in Table 12. Data for irradiated and control fresh beef are given in Table 13. Texas A & M strain rats were used in these tests.

Since similar results were obtained with dried and fresh beef, dried beef is used as starting material in all tests at the present time.

Chloroform Extraction.

Dried irradiated beef was extracted with U.S.P. Chloroform. Prothrombin times of rats at 4 and 6 weeks receiving the residue and chloroform soluble fraction are summarized in Table 14. The activity was left in the residue, and prothrombin times was higher in every animal at 6 weeks than at 4 weeks. Likewise, prothrombin times of control animals were slightly higher at 6 than at 4 weeks, but the values for the control animals were considered normal.

Ether Extraction.

Prothrombin times of rats (Holtzman strain) at 4 weeks receiving the residue and ether soluble fraction of irradiated dried beef are summarized in Table

TABLE 12

Prothrombin Time (Seconds) of Blood Plasma and Weights of Individual Rats Receiving Irradiated and Non-Irradiated Dried Beef.

PROTHROMBIN (Sec)				WEIGHT (gms)			
Irradiated		Control		Irradiated		Control	
6 wks	12 wks	6 wks	12 wks	6 wks	12 wks	6 wks	12 wks
14	19	14	12	313	400	278	370
27	27	17	14	243	290	238	325
18	32	16	14	244	255	241	290
28	46	-	15	245	325	221	315
35	-	12	10	193	-	207	335
30	51	12	29	216	292	250	310
47	17	11	13	215	238	202	415
24	19	14	-	240	318	230	338
35	19	13	-	210	280	202	-
30	-	12	15	243	-	274	440
AVG. 29	28	14	15	236	300	234	349

TABLE 13

Prothrombin Time (Seconds) of Blood Plasma and Weight of Individual Male Rats (Texas A&M Strain) Receiving Irradiated and Non-Irradiated Fresh Beef.

PROTHROMBIN (Sec)				WEIGHT (gms)			
Irradiated		Control		Irradiated		Control	
6 wks	12 wks	6 wks	12 wks	6 wks	12 wks	6 wks	12 wks
13	19	15	16	338	443	318	420
14	15	20	21	208	346	326	452
22	17	13	16	315	448	178	290
15	10	10	19	244	380	274	360
28	19	16	16	206	298	281	422
35	15	13	20	268	382	294	435
50	-	13	20	272	385	257	385
38	15	15	19	178	290	250	382
33		15	19			253	375
		13	15			239	365
AVG. 28	16	14	18	254	372	267	389

TABLE 14

Prothrombin Time of Plasma of Individual Male Rats (Texas A&M Strain) Receiving Residue and Extract From Chloroform Extraction of Dried Irradiated Beef.

PROTHROMBIN - SECONDS

Residue		Chloroform Soluble	
4 wks	6 wks	4 wks	6 wks
13	20	17	17
16	20	11	16
27	30	-	17
25	104	10	17
41	45	13	18
-	35	13	16
12	25	10	15
-	26	-	15
		15	21
		12	16
AVG.22.0	38	13	17

TABLE 15

Prothrombin Time of Plasma of Individual Male Rats (Holtzman) Receiving Residue and Extract From Ether Extraction of Dried Irradiated Beef.

PROTHROMBIN AT 4 wks. - SECONDS

RESIDUE	EXTRACT
40	12
21	15
24	15
85	15
155	28
14	14
14	13
64	13
Two animals died and thoracic cavity was filled with blood	18
AVG.52	16

Again the rats receiving the residue had prolonged prothrombin times. The prothrombin times were longer than that of rats receiving control beef and two animals had died at three and four weeks with thoracic cavity filled with blood. The animals in this test were obtained from the Holtzman Company.

No spontaneous hemorrhages have occurred in Texas A & M rats and the difference between the A & M strains and the Holtzman strains illustrate the susceptibility of different strains of rats to the hemorrhagic syndrome.

Combination ofResidue and Ether Soluble Fractions.

The rats, Holtzman strain, receiving the residue from the ether extraction of dried irradiated beef grew at a slightly slower rate than those receiving the whole dried irradiated beef. It was thought this difference in growth might have been due to the energy content of the diet. In view of this probability, tests were carried out with a combination of the residue and ether soluble fractions. In one test the irradiated residue was combined with ether soluble fraction of the control beef. In a second test, the control residue was combined with the ether soluble fraction of the irradiated beef. These results are summarized in Table 16. The prothrombin times of all rats receiving the irradiated residue and control extract were normal, while the average prothrombin time of the rats receiving control residue and ether soluble fraction from the irradiated beef was longer than that of the first group. Three had prothrombin times over 20 seconds and normally these would be considered slightly hemorrhagic.

The observation that ether soluble fraction of the irradiated beef was more effective than the residue when these fractions were combined with fractions from the control beef is not understood from these preliminary results.

TABLE 16

Prothrombin Time of Plasma of Individual Male Rats (Holtzman) Receiving Combination of Residue and Extracts from Ether Extraction of Dried, Irradiated, and Non-Irradiated Beef.

PROTHROMBIN TIMES AT 4 WKS.	
Irradiated Residue Control Ext	Non-Irradiated Residue Ether Soluble
15	25
14	18
14	16
15	26
13	16
12	16
13	21
12	
AVG.14	20

Cod Liver Oil VS A-D Conc.

The prothrombin times of individual rats (Holtzman) at four weeks receiving cod liver oil and wheat germ oils and of those received an A-D conc. and alpha tocopherol as sources of the fat soluble vitamins are summarized in Table 17. The hemorrhagic disease developed in some of the rats in both groups but the average prothrombin time was slightly shorter in the groups receiving cod liver and wheat germ oils than in the one receiving vitamin A-D concentrate and alpha tocopherol. These data show that cod liver and wheat germ oils are not essential for producing the syndrome.

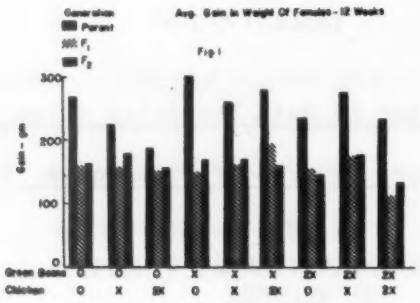
R-25

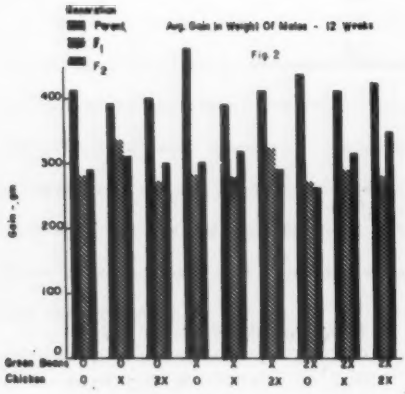
TABLE 17

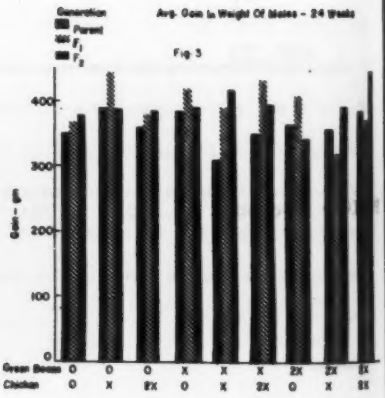
Prothrombin Time of Rats Receiving Dried Irradiated Beef and Different Sources of Vitamins A, D and E.

PROTHROMBIN TIME AT 4 WEEKS IN SECONDS	
Cod Liver Oil Wheat Germ Oil	A-D Conc. A-tocopherol
14	45
14	20
24	24
46	20
19	17
33	32
15	30
17	36
AVG. 23	28

R-26
(Final)


Generation
Parent
F1
F2
Avg. Gain in Weight Of Females - 12 Weeks
Fig. 1
Gain - gm
300
200
100
0
Green Beans 0 0 0 X X X 2X 2X 2X
Chicken 0 X 2X 0 X 2X 0 X 2X


Generation
Parent
F1
F2
Avg. Gain in Weight Of Males - 12 Weeks
Fig. 2
Gain - gm
400
300
200
100
0
Green Beans 0 0 0 X X X 2X 2X 2X
Chicken 0 X 2X 0 X 2X 0 X 2X


Generation
Parent
F1
F2
Avg. Gain in Weight Of Males - 24 Weeks
Fig. 3
Gain - gm
400
300
200
100
0
Green Beans 0 0 0 X X X 2X 2X 2X
Chicken 0 X 2X 0 X 2X 0 X 2X

R-27

Progress Report

POSSIBLE CARCINOGENICITY OF IRRADIATED FOODS

by

HARRY MONSEN

University of Illinois, College of Medicine

PERIOD: October 15, 1958 to March 15, 1959

Department of the Army
Office of the Surgeon General
Medical Research Contract
No: DA 49-007 - MD-794

The experimental plan, including detailed description of diet composition and of the pedigreed mice employed was reported to the Office of the Surgeon General, March 15, 1958.

A diet composed of irradiated pork loin, chicken, evaporated milk, blanched carrots (irrad. level: 6 mill. rep.) and white potatoes (inad. level: 10,000 - 12,000 rep.) has been fed to Strong A and Cb mice since February 5, 1958. Littermate controls have been fed a non-irradiated diet, identical in composition to that above, and a diet of Purina Laboratory Chow. A complete supplement of vitamins is added to the irradiated and non-irradiated diets.

No final data regarding the possible carcinogenicity of the irradiated diet can be presented at this time, but the nutritional adequacy and acceptability may be commented upon.

Strong A

In this strain of mice there is no significant weight difference between animals on irradiated and non-irradiated diets. The average food consumption per mouse, per day is 13 g. on a wet weight basis. (mouse weight: 36 - 38 g.). Littermate controls on Laboratory Chow pellets weigh on the average 2 g. less.

The mortality rate has been very low in al. groups. Of the original 409 males and females on irradiated diet, 20 animals are dead (5%). Four males and four females died within 3 - 5 days after having been placed on the diet. These animals died because of inability to adapt to the experimental diet ("starved") and were all replaced. The remaining 12 animals exhibited the following pathological findings:

1, Mammary cancer.

3, Hemorrhagic G.I. tracts, primarily involving colon.

1, Lung congestion.

3, Ruptured left auricle of the heart.

4, No obvious pathology because of post mortem changes.

In the "non-irradiated" group the mortality rate is 4.2% (15 deaths of a total of 387 males and females). Six animals "starved." The remaining 9 exhibited the following pathology:

3, Mammary cancer.

1, Overgrown lower incision.

1, Kidney damage.

4, Unknown (partly or completely eaten up).

Only one animal has died in the Laboratory Chow group of littermate controls. (Total number of 182 males and females).

Summary of findings in Strong A mice:

No data are yet available as to the possible carcinogenicity of the diet. Only the heart lesion (left auricular dilatation) seems to be related to the consumption of irradiated diet. This assumption is made on the basis of findings in another strain (Cb).

Cb

There is no significant difference in growth rates between healthy animals of the Cb strain fed irradiated, non-irradiated diets and Laboratory Chow. The mortality rate is higher in the "irradiated" groups of males and females because of a lesion afflicting the left auricle of the heart leading to dyspnea, debilitation and ultimately death due to rupture of the dilated auricle.

Of the original 390 males and females in the "irradiated" group, 44 deaths have been recorded (11.2%). Thirty-five animals (19 males and 16 females) have died or have been killed because of dilated auricles. The average latent period for the development of this condition is 85 days (from the time of initiation of feeding) although an occasional animal has been killed after having been on the diet only 48 - 52 days. The pathology report is not yet complete. Specimens have been forwarded to the Armed Forces Institute of Pathology and further work is being done at this institution.

No lesion of this type has been seen in 400 males and females of the "non-irradiated" groups. Nineteen animals, 9 males and 10 females are now dead (4.8%). The autopsy findings were as follows:

2, "Starved".

2, Accidental death (caught in food hopper and crushed head).

6, Hemorrhagic colon and small intestine.

1, Pneumonia?

8, No gross pathology (because of advanced post mortem changes)

All littermates (190 males and females) on Purina Laboratory Chow are still alive.

Summary of findings in Cb mice:

No data are as yet available on the possible carcinogenicity of the irradiated diet. Nine per cent of males and females on the irradiated diet have died or been killed because of dilated or ruptured left auricles. This lesion has never been seen before in this laboratory and seems to be restricted primarily to mice of the Cb strain on an irradiated diet (three cases have been observed in Strong A mice on an irradiated diet).

Mons-4
(End)

MASTER FOOD & CONTAINER INSTITUTE
1819 WEST PERSHING ROAD
CHICAGO 9, ILLINOIS

Appendix 3

Final Report

Logistic and Economic Feasibility Study on Radiation Sterilization of Foods

Official Investigator: R. J. Beeley
North American Aviation, Inc.

Contract No: DA19-129-QM-491

S-543 - Rpt #6

Period: 28 June 1955 - 28 August 1956

QUARTERMASTER FOOD AND CONTAINER INSTITUTE FOR THE ARMED FORCES
Research and Development Command
Quartermaster Corps, U.S. Army
Chicago, Illinois

CONTRACT RESEARCH PROJECT REPORT

QUARTERMASTER FOOD AND CONTAINER INSTITUTE FOR THE ARMED FORCES, CHICAGO, Hq., QM Research and Development Command, QM Research and Development Center, Natick, Mass.

North American Aviation, Inc.
International Airport
Los Angeles 45, California

Official Investigator: R. J. Beeley
J. C. Dillon
R. J. Mikell
C. O. Reiser
E. C. Turner

Project No.: 7-84-01-002
Contract No.: DA19-129-QM-491
File No.: 8-543
Final Report No.: 6
Period: June 1955 - 28 August 1956
Initiation Date: June 28, 1955

Title of Contract: Logistic and Economic Feasibility Study on Radiation Sterilization of Foods

ABSTRACT

This report summarizes the results of a study for the Quartermaster Corps under Contract No. DA19-129-qm-491. The purpose of the study was to survey all of the known radiation sources of sufficient size to be of interest in large - scale radiation processing, to determine the most economic radiation source for this purpose. The sources considered in this study are the following:

1. Spent reactor fuel elements
2. Fission-product gases from a fluid fuel reactor
3. Separated fission-product cesium - 137
4. Reactor coolant sodium - 24
5. Neutron-activated indium - 116m
6. Charged-particle accelerators
7. X -rays

Additional sources which are of sufficient size to be of interest are gammas directly from a reactor core and the decay gammas in circulating-fuel reactors. Since no specifications were available as to the permissible neutron levels, these sources were eliminated from consideration.

Preliminary designs and capital cost estimates were obtained for facilities using each of the above radiation sources with the exception of X-rays, which were eliminated on an economic basis by comparisons with the accelerator. For each of the first six sources, estimates of capacity and capital costs per unit of output were obtained and the results compared to determine the most economic radiation source for food processing.

The designs presented are not optimized; different conveyor arrangements, source configurations, shield and labyrinth designs, etc. should lead to improvements in over-all processing costs. Design variations were limited by the scope of the study.

The designs of the food-handling conveyors and their costs were prepared by the Food Machinery and Chemical Corporation under a subcontract. The remainder of the study was made at Atomics International, a division of North American Aviation, Inc.

SUMMARY

The estimated costs of processing with the radiation sources considered are as follows:

	Exposure	
	2.5×10^6 Reps	10^5 Reps
Spent Fuel Elements	2.050¢/lb	0.0820¢/lb
Gaseous Fission Products	0.360¢/lb	0.0144¢/lb
Separated Cesium-137*	0.379¢/lb	0.0152¢/lb
Sodium-24	0.648¢/lb	0.0260¢/lb
Reactor-Activated Indium	1.402¢/lb	0.0560¢/lb
Electron Accelerator (7.5-kw)	0.548¢/lb	0.0722¢/lb
Electron Accelerator (50-kw)	0.235¢/lb	0.0854¢/lb

*Does not include the cost of the cesium source.

52249 O—60—pt. 1——31

The conclusions of the study are the following:

1. For irradiation of foods to sterilization (2.5×10^6 reps) the most economic source of radiaton is the large accelerator.
2. For low exposures (10^5 reps), by-product gamma sources are most economic for radiation processing.

The conclusions of the study are discussed in detail in Section X.

I. INTRODUCTION

Radiation processing of foods has been proposed as a method of sterilization or pasteurization. In the process the food is exposed to the ionizing effects of irradiation by charged particles, such as electrons, or by electromagnetic radiation of short wavelength, such as gamma and X-rays. The ionization destroys the microorganism causing spoilage - the fraction destroyed depending on total "exposure," or quantity of radiation energy absorbed in the food.

The exposure is measured in reps, the rep being a unit of energy absorbed per unit mass and is equivalent to 93 ergs per gram. In more familiar units, 10^6 reps corresponds to 2.2 calories per gram or about 4 Btu per pound. The amount of exposure required depends upon the process in question and the population density of microorganisms in the material to be processed. Fresh meat can normally be sterilized with irradiation to about 2.5×10^6 reps, or about 5.5 calories per gram. Fresh meat can be pasteurized for the extension of shelf life with irradiation to about 10^5 reps. Flours and grains can be de-infested with $1-3 \times 10^5$ reps; sprouting in potatoes can be controlled with 1.5×10^4 reps.

Radiation processing therefore has possible applications to a variety of foods, and in some cases the process is unique; for example, this is the only known way of preserving fresh meats and produce for an extended period of time without refrigeration. Therefore, radiation processing of foods could be very useful in meeting the logistics problems of the Armed Forces and also have applications in commercial marketing practice.

The primary basis for comparisons of the various radiation sources is the cost per pound of product processed, although consideration is also given to the length of time required for processing and to the possibility of producing radioactivity in the food.

For purposes of cost comparisons, only partial processing cost estimates have been made. The partial costs are those associated with the establishment and utilization of the radiation field required for the process; they are thus comparable to the costs of providing heat and cooking equipment for a thermal process or to the costs of providing quick freezing and continuous refrigeration for frozen-food processes. The costs of packaging, handling, storing, etc. are neglected.

In detail, the items which are included in the partial cost estimates are:

1. *The radiation source.* This is the electron accelerator or the gamma-emitting material and gamma radiator to provide the radiation energy.
2. *The radiation chamber.* This includes the radiation shield with footings, removable plugs where required, and labyrinths for food conveying equipment.
3. *Source equipment.* Included here are cooling systems, secondary containment envelopes, means of removing the source from the chamber, emergency power supplies, decontamination equipment, and required instrumentation. Dosimeters included are limited to those required for measurements of the radiation field.
4. *Food-handling conveyors.* The conveyors provided are those required for carrying food packages into the radiation chamber, for exposing the packages to the radiation field in the chamber, and for removing the packages from the chamber.

It must be emphasized that the cost estimates obtained for these components of the radiation facilities are based on preliminary designs and that the number of figures given does not reflect the accuracy with which these costs are known.

In addition to the above capital costs, some operating costs - unique to one of the radiation sources - are included. These are the following:

1. *Power costs for the electron accelerator.* The source of radiation energy from the accelerator is the electrical power input, and this cost is included.
2. *Cost of replacement parts for the accelerator.* The electron gun and cathode will require periodic replacement.
3. *Fuel costs for the reactor in which indium sulfate is activated.*

Additional operating costs which might be included in this list are mentioned in the discussion of cost estimates for each of the radiation sources.

In making the estimates of unit processing costs, it was assumed that the radiation facilities would be operating continuously because of the high capital investment required. Since some down-time is required for maintenance, the plant factor was taken to be 90 per cent. The annual charge on capital investment was taken to be 15 per cent.

To determine the economic feasibility of radiation processing, it is necessary to make comparisons with alternative processes. In radiation processing the energy requirements are relatively low. For instance, a sterilizing exposure of 2.5×10^6 reps is equivalent to 9.9 Btu per pound, while the thermal energy requirement for sterilization may be 200 Btu per pound. The energy requirement for quick freezing, followed by continued refrigeration until the food product is consumed, is even higher.

Radiation energy is so much more expensive than thermal or electrical energy that there is considerable doubt that the irradiation process can ever compete with thermal processes purely on the basis of cost of the process. However, there is a unique advantage to radiation processing which could easily outweigh the processing cost disadvantage. This is the fact that the processed foods are not only as fresh as they are from the freezing process, but may be stored in the same manner as foods from a cooking process, i.e., without refrigeration.

This fact that fresh foods processed by radiation can be stored and transferred without use of expensive and frequently inconvenient refrigeration equipment indicates that there can be little doubt that the process will be used. The extent to which it will be used depends upon the cost of the process. The unit processing cost obtained in this study is some fraction of a cent per pound; this is so minor compared to the value of the food product that it seems inevitable that radiation processing will be used on a large scale in the food industry.

II. CONSIDERATIONS IN THE DESIGN OF A RADIATION PROCESSING PLANT

The arrangement of radiation source and food handling equipment, required energy of the radiation, conveyor speed, and source strength required for the process depend upon the exposure required and density of the process material. When the study was initiated, exposures from 1.5×10^4 to 2.5×10^6 reps were specified in materials of a wide range of densities, sizes and shapes. An attempt was made to obtain a preliminary design for each of the radiation sources which would handle the entire range of materials and required exposures. The attempt was successful in most cases; restrictions on exposure are discussed in Section X.

The important factors to be considered in the design of a radiation facility are the source configuration, source strength, conveyor arrangement, exposure variations, source cooling and containment, and provisions for maintenance. Each of these is discussed in the following paragraphs.

A. SOURCE CONFIGURATION

For the electron accelerators there is no problem with source configuration; since the electrons in the beam are essentially monodirectional, the item to be irradiated is passed through the beam. In order to obtain uniform exposure and to permit the processing of large packages, the beam is scanned back and forth across the package as the package moves through the beam. There is some variation in exposure with depth in a process item of uniform density, and additional variation will be obtained in nonuniform materials. The variation is discussed in Section II, D.

The gamma-ray sources produce radiation in all directions, and several geometrical configurations are possible; food handling convenience, uniformity of exposure and utilization of the available gamma energy must be considered in making the choice of source geometry. Possibilities include a long cylinder of radioactive material, a sphere, a hollow cylinder or drum with several processing tubes, or a rectangular slab. However, the long cylinder and the sphere appear impractical due to problems of exposure variation and gamma utilization.

The foods considered for processing in this study include fresh meast in large and small packages, grains, flours, baked goods, fruits, and vegetables. These foods would be contained in No. 2 cans, No. 10 cans, plastic bags, sacks, or V3 boxes. The latter is a pressed paper carton with a volume of one cubic foot and with over-all dimensions of 6 inches x 15-1/2 inches x 20-1/2 inches. As discussed in the section on Conveyor Arrangement, Section II, C, all conveyors presented in this report are designed for the V3 box. With this container, the slab source arrangement appears to be the most attractive possibility and all of the sources presented are of this geometry.

B. SOURCE STRENGTH

"Source strength" is the gamma or electron energy available per unit time. With the accelerator, it is the average electron-beam power. For the gamma

sources, it is the product of the number of radioactive disintegrations per unit time multiplied by the average gamma energy emitted per disintegration. For both types of sources it is convenient to measure source strength in kilowatts. Since gamma sources are usually measured in curies or megacuries, a convenient conversion is the following: a one megacurie (10^6 curies) source of a material emitting 1 Mev of gamma energy per disintegration has a gamma power of 5.92 kilowatts.

The processing capacity of a radiation plant is proportional to the source strength. Because of losses, the radiant energy absorbed in the process item is always less than the source strength. The radiant energy is lost by (1) self-absorption in the source, in the case of gamma sources; (2) by missing the process item completely; (3) by passing through the process item without complete absorption. With the accelerator, some of the electron-beam energy is lost in the production of bremsstrahlung, or high-energy X-rays, which are not absorbed in the food to an appreciable extent; in addition a small fraction of the beam energy is absorbed in the air between the beam window and the food package.

Two beam powers for the accelerator were selected for processing cost estimates; these are 7.5 and 50 kw. With the lower beam power, potatoes can be processed to 1.5×10^4 reps. With the larger machine the minimum exposure is 10^5 reps. Restrictions on exposure with the accelerator are discussed in Section VIII.

The gamma source strengths used in the study depend upon the source of radioactive material. For the fuel element facility, a slightly-enriched uranium fuel element from a single 250-Mw reactor was used. Only 14 fuel elements per month are discharged from the reactor, and the maximum gamma power is fixed by the reactor operating conditions and length of time the fuel elements are held in the irradiation facility. The sodium used for source material is a small part of the sodium coolant in a power reactor. The sodium volume assumed in the radiation cell is such as to provide a gamma power of 28.4 kw - about the source strength required for the QMC processing pilot plant. The strengths of the rest of the gamma sources were chosen also in a somewhat arbitrary manner as discussed in the sections concerned with each of these sources.

C. CONVEYOR ARRANGEMENT

All of the conveyors presented in this report are designed to handle the V3 boxes. These are pressed paper cartons with an internal volume of 1 cubic foot and over-all dimensions of 6 inches by 15-1/2 inches by 20-1/2 inches. This carton could conveniently be used as a container for all of the packages and materials required excepting the No. 10 cans.

The conveyors for the accelerator facilities are single-belt units handling a single line of V3 boxes. There are two accelerator facilities presented, one with a single accelerator and the other with two. The conveyor carries the boxes through the beam, which is scanned across the box in a direction normal to the direction of conveyor movement. The boxes are exposed to the electron beam from both ends of the six-inch dimension of the V3 box. With two machines, the opposite sides are exposed simultaneously. With the single machine, the conveyor exposes first one side then the other to the electron beam.

The conveyors for the gamma facilities are multibelt units with three or four parallel conveyors moving along the faces of the slab-type gamma sources. The food package follows a path which carries it to both sides of the slab source, presenting opposite faces to the two sides of the source. Several of the gamma sources consist of more than one plaque; this is necessary because of the low specific activity (dis/sec-cm^3) of some of the sources, and requires that a long conveyor be used.

Some details of the conveyor systems are presented in the sections dealing with each radiation source.

D. EXPOSURE VARIATIONS IN THE PROCESS MATERIALS

The variation of exposure from an electron beam can be computed with reasonable accuracy. The depth of penetration, or range, of the electrons in a material is a function of the electron energy and the density of the material. The range in centimeters is given by the expression

$$R_{max} = (0.542E - 0.133)/\rho \quad (E>0.8\ Mev)$$

where E is the electron energy in Mev, ρ is the target density in gm/cm^3 and R

is in centimeters. The accelerator is suitable for surface processing or processing in depth, depending upon the electron energy.

The exposure varies with depth, reaching a maximum at about 1/3 of the range as indicated in Fig. 1. The peak in the exposure rate curve is caused by ionization due to recoil electrons which are relatively less numerous near the surface of the target. The curves of Fig. 1 are for monoenergetic electrons. With the spectrum obtained from a high-energy linear accelerator, in which the electron energies deviate by perhaps 10 per cent from the design energy, the exposure at the surface is about 90 per cent of the peak, and the variation in exposure with depth in a target of uniform density can probably be held to 10 per cent.

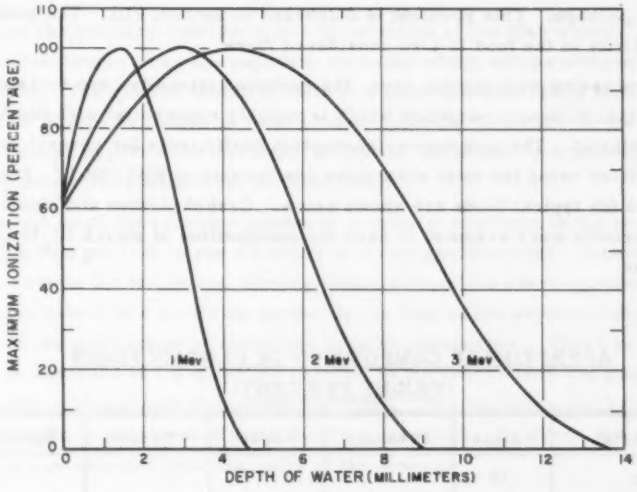


Fig. 1. Distribution of Radiation Exposure in H_2O

Irradiation of large packages with electrons from only one surface would require high electron energy and would waste part of the beam energy; since it would be necessary to adjust the electron energy so that the exposure at the exit surface of the package is equal to the exposure at the entering surface, some of the electrons would pass completely through the package. By irradiating the

package from opposite sides the electron energy can be reduced and the beam utilization increased.

The largest food package considered in this study, the V3 box, has a smallest dimension of six inches. By irradiating from both sides, an electron energy of about 18 Mev is sufficiently high to result in minimum exposure variation in a package of unit density.

The distribution of electrons in the beam is roughly Gaussian across its circular cross section. Uniformity of exposure across the package is obtained by scanning the beam from side to side. The beam is not continuous; the electrons are emitted in pulses and the beam cannot be scanned at a greater speed than that which spaces pulses more than about one half the beam diameter on the surface of the food package. This problem is discussed in Section VIII. The problem of induced activity in the food is also considered there.

In processing with gamma rays, the radiation intensity, and therefore the exposure rate, follows a variation which is roughly exponential with depth in the process material. The gamma-ray absorption coefficients for several foods were calculated using the total absorption coefficients of NBS-1003.[1] The compositions used for typical foods are shown below. Carbohydrates and small amounts of fat and protein were assumed to have the composition of starch $(C_6H_{10}O_5)_n$ for this purpose.

APPROXIMATE COMPOSITION OF CERTAIN FOODS

(WEIGHT PER CENT)

Material	Meat	Potatoes	Flour	Bread	Spinach
Carbon	18				
Hydrogen	10				
Oxygen	65				
Nitrogen	3				
Water		78.6	12.0	35.9	92.7
Protein		2.0	10.8	8.5	2.3
Fat			0.9	2.0	0.3
Carbohydrate		19.4	75.9	52.3	3.2
Fiber				0.2	

COMPOSITION OF FOODS USED IN CALCULATIONS

(WEIGHT PER CENT)

Material	Meat	Potatoes	Flour	Bread	Spinach
Carbon	18.8	9.5	39.2	28.4	2.6
Water	76.2	90.5	60.8	71.6	97.4
Hydrogen	1.9				
Nitrogen	3.1				

The gamma-ray absorption coefficients thus obtained are shown in Fig. 2 and 3 as a function of gamma energy.

One of the primary considerations in selection of the slab-source geometry for the gamma sources was the exposure variation which will be obtained in the process item. The gamma radiation field in a plane parallel to the face of a uniform slab source or plaque is most intense opposite the center of the source and least intense opposite the corners. Exposure variations in a package moving across the face of the plaque must be considered.

The motion of the conveyor produces a uniform exposure in the process item along a line parallel to the direction of travel (y-direction). Attenuation of gamma rays in the target and varying distance from the source produce exposure variations in a direction normal to the face of the plaque (z-direction). Variation in the z-direction is discussed in later paragraphs. There is also variation in exposure in the direction parallel to the source face and perpendicular to the direction of conveyor travel (x-direction). This variation can be minimized by arranging the source nonuniformly in the x-direction. In effect, the source material is concentrated near the sides of the source.

In Fig. 4 the radiation intensities from a uniform and nonuniform slab source are compared; the total source activities are the same. The source distribution in the nonuniform plaque is indicated in Fig. 5. Figure 4 and 5 apply to a source 10 feet by 18 feet; the gamma sources of this report are of varying sizes, but the same type of distribution is used.

The nonuniform source can be arranged to give approximately constant radiation intensity in the x-direction at only one distance from the source. At

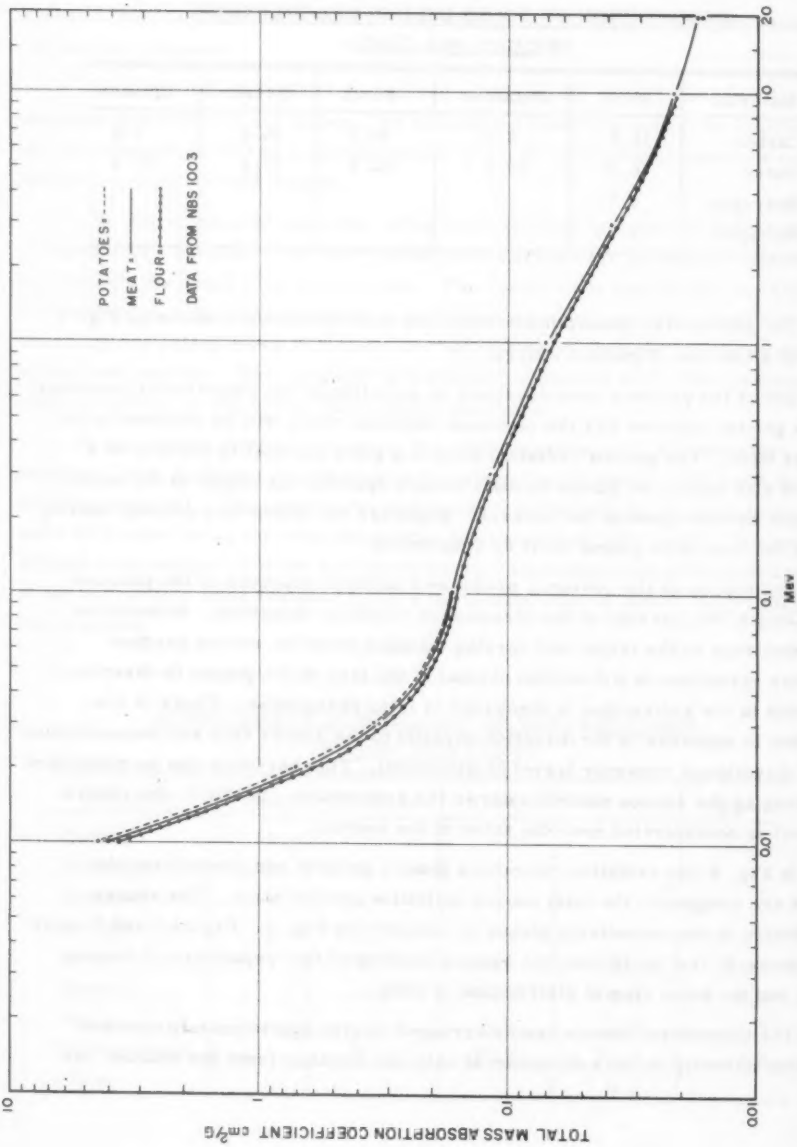


Fig. 2. Total Gamma Absorption Coefficients (Meat, Potatoes, Flour)

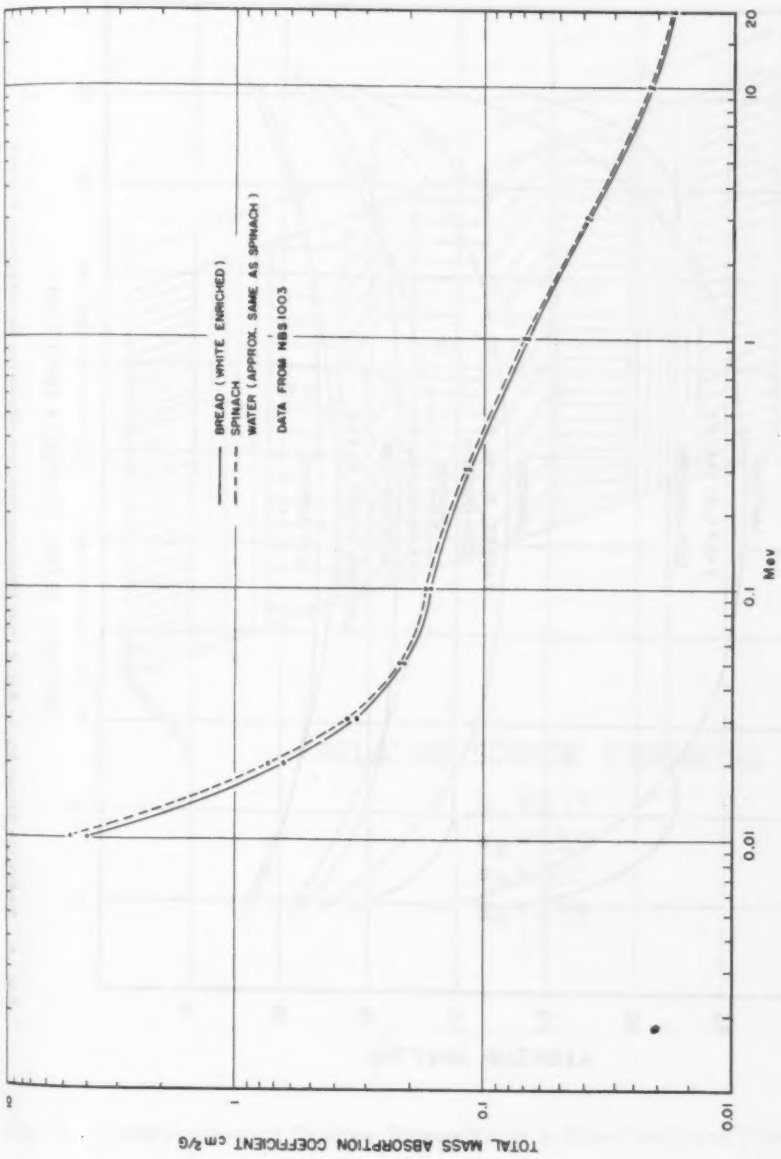


Fig. 3. Total Gamma Absorption Coefficients (Bread, Spinach, Water)

Fig. 2. Total Gamma Absorption Coefficients (Meat, Potatoes, Flour)

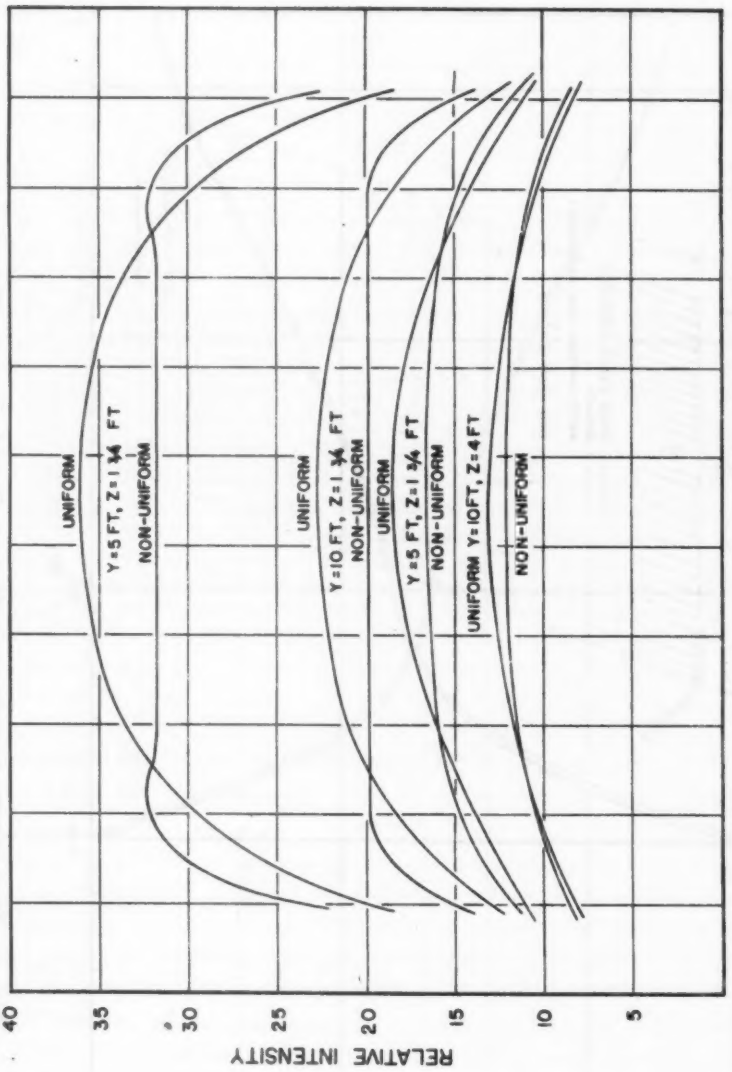


Fig. 4. Radiation Intensity in Air From Uniform and Non-Uniform Rectangular Source

Fig.

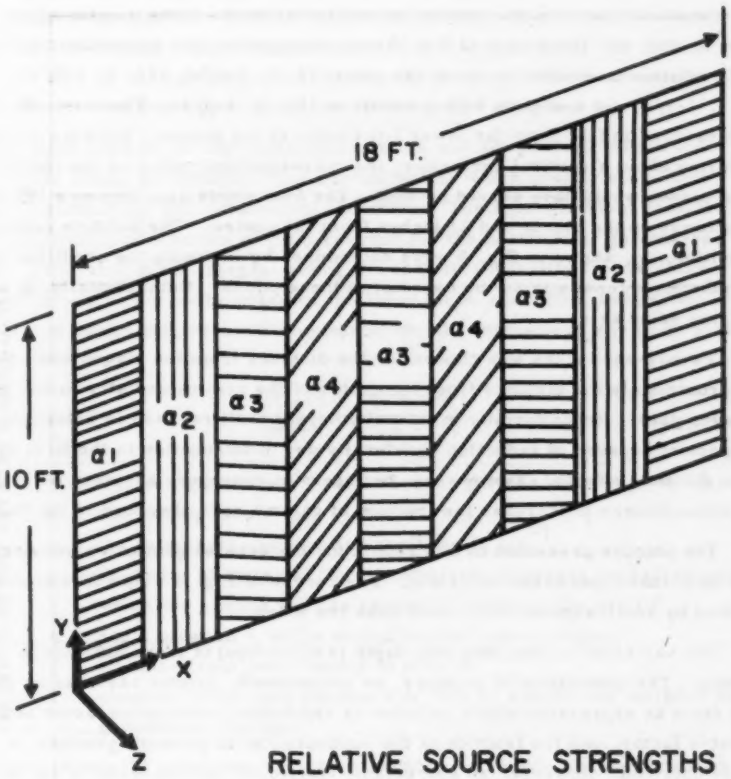


Fig. 5. Distribution of Source Intensity in a Non-Uniform Plaque

Fig. 4. Radiation Intensity in Air From Uniform and Non-Uniform Rectangular Source

different distances from the source, intensity variations along x again appear as shown in Fig. 4. The plaque of Fig. 5 was arranged to give approximately constant radiation intensities in air at the points (9, 5, 1-3/4), (12, 5, 1-3/4), (14, 5, 1-3/4) and a slightly high intensity at (16, 5, 1-3/4). These co-ordinates are measured in feet from the lower left corner of the plaque. Because of the symmetry about a vertical centerline, the corresponding points on the left half of the plaque would have served as well. The four points used are on a horizontal line midway up the plaque and 21 inches from the center. The relative source intensities, a_i, shown in Fig. 5 were determined by imposing the condition that the radiation intensity in air be constant at these points. Coincidentally, a_2 has the same value as a_4.

Twenty-one inches was chosen for the distance from the plaque since this is approximately the distance from the center of the gamma radiator to the nearest conveyor pass. Nonuniformity in intensity beyond the first pass is relatively unimportant because of reduction in intensity due to attenuation in the first pass and to distance effects. Two passes, or layers of conveyor, are used on each side of the source to increase the fraction of gamma rays absorbed in the food.

The plaques presented in this report for the several gamma sources are made up of tubes spaced nonuniformly. The curves of Fig. 4 would therefore be modified by small ripples which peak near the tubes.

The variation in exposure with depth (z-direction) is more difficult to compute. The attenuation of primary, or unscattered, gamma rays can be computed from an expression which includes an exponential absorption factor and a geometry factor, and the fraction of the exposure due to primary gammas is readily obtained. However, an appreciable fraction of the exposure is due to scattered gammas, and this fraction is difficult to compute except in highly-idealized situations. The ratio of total exposure to the exposure from primary gammas is termed the "buildup factor."

Calculation of the buildup factor is an involved process even in idealized situations; tables and curves of buildup factors for several materials have been published[1] for point and infinite-plane sources in infinite-absorbing media.

The correct buildup factor to use, for the finite slab gamma sources assumed with a finite-absorbing medium, is somewhere between unity and the

values published for infinite media. Neglect of buildup would overestimate the gamma-ray attenuation in the food package and thus overestimate the exposure variation. Use of buildup factors for infinite media would underestimate the exposure variation; thus upper and lower limits can be obtained.

Detailed analysis of the exposure variation was not possible within the scope of this study; the validity of an approximation which greatly simplifies exposure calculations was established, however. The approximation consists of the substitution of a series of point sources for the rectangular gamma-ray source. The value of the integral giving the radiation intensity from a finite rectangular source cannot be obtained in closed form; numerical integration is required. With the point-source approximation, the intensity at any point P is given by:

$$D = \frac{C}{4\pi} \sum \frac{S_i Br \exp[-\mu t/\cos\theta]}{r_i^2}$$

where S_i = the strength of the i^{th} point source, photons/sec

Br = the buildup factor

μ = the gamma-ray attenuation coefficient, cm^{-1}

t = thickness of material (food, container, conveyor basket) through which the gamma ray has passed in reaching the point P

θ = angle between r_i and a normal to the source plaque

r_i = distance from point source to point P

C = constant converting photons/cm^2-sec to rep/hr and includes the gamma-ray energy.

In checking the point-source approximations, a source plaque 10 feet by 18 feet was broken into squares 1.5 feet on a side, and the radioactivity associated with this area was assumed to emanate from a point at the center of the square. The radiation intensity in air was computed at several points in a paralled plane 1.5 feet from the source. The results were compared to those obtained by numerical integration, and were within 1 per cent in all cases. Additional calculations were made dividing the source plaque into squares 3 feet on a side. In this case the maximum error was 5 per cent. Thus the point source approximation gives good results provided the divisions of the source plaque are such that each section has dimensions no greater than about twice the distance to the plaque from

52249 O—60—pt. 1——32

the point at which the radiation intensity is desired. The error obtained by this approximation will be masked by the uncertainties resulting from approximations of the buildup factor.

E. SOURCE COOLING AND CONTAINMENT

The accelerator has an internal cooling system which removes heat from the electrical and electronic equipment associated with the machine; cooling is a minor problem. The only containment problem foreseen for the accelerator facility is concerned with activity induced in those parts of the food-handling conveyor which are exposed to the electron beam. This is discussed in Section VIII.

All of the gamma sources need cooling because of the heat generated in the gamma emitter by self-absorption of betas and a fraction of the gammas. For those gamma sources which are liquid and are circulated through the source plaque, the cooling is done outside the food-irradiation cell. For the fixed sources including the gaseous fission products, cooling is provided at the source plaque. The cooling system for each of the gamma sources is discussed in the section dealing with that source.

The problem of containment is more serious with the gamma sources than with the accelerator since food contamination could result from a leak in the gamma source. To avoid the possibility of food contamination, all of the gamma sources of this study are contained in two envelopes with a monitoring fluid, gas or liquid, between the envelopes.

F. PROVISIONS FOR MAINTENANCE

It is expected that the food-irradiation cell in an electron-accelerator facility could be entered shortly after machine shutdown, and maintenance of equipment can follow normal procedures.

With the gamma sources, the source must be removed from the radiation cell or the conveyor system must be removed from the cell for maintenance. The liquid gamma sources can be drained and the system flushed with decontaminating solutions to remove the activity. It may be necessary to wait for trace amounts of activity to decay. The solid sources can be removed mechanically from the irradiation cell.

The only gamma source which appears to be difficult to remove from the radiation cell is the gaseous fission products. Deposition of radioactivity on the walls of the source plaque must be expected. While flushing with decontaminating solutions will remove most of the deposited activity, waiting for trace amounts to decay seems impractical because long half lives are involved. There is only one radiation plaque in the preliminary design presented for this source; the conveyor system is therefore simpler than those for the other gamma sources, and provision is made to remove the conveyor from the radiation cell for maintenance.

III. RADIATION FACILITY USING SPENT REACTOR FUEL ELEMENTS

Used reactor fuel elements contain relatively large quantities of radioactive fission products. These emit betas and gammas. The betas are almost entirely absorbed in the fuel element material; some fraction of the gammas escape the element and are available for processing. Because of the great variety of radioactive isotopes in gross fission products, rather involved calculations are required to obtain the source characteristics.

A. CHARACTERISTICS OF GROSS FISSION PRODUCTS

Several analytical studies of gross fission products have been made recently.[3,4,5] The analytical procedure is to list all of the known fission products, compute their buildup in a reactor and decay after removal, and estimate the gamma power output. Unfortunately, the decay schemes of some of the isotopes are not well known and assumptions have to be made in many instances. All the previous studies[3,4,5] have been concerned with shielding computations. In instances where data are lacking the tendency was to be conservative from a shielding standpoint; that is, to overestimate gamma power and especially to avoid neglect of a hard (high energy) gamma even with a low yield since these determine the required shield thickness. In the present study conservatism is on the side of underestimating both gamma energy and power, and a complete recalculation of gamma activity in gross fission products was required.

The differential equations governing the buildup of the various fission products of each mass chain are as follows:

$$\frac{dN_1}{dt} = yF - \lambda_1 N_1$$

$$\frac{dN_2}{dt} = \lambda_1 N_1 - \lambda_2 N_2$$

$$\frac{dN_3}{dt} = \lambda_2 N_2 - \lambda_3 N_3$$

where N_i = concentration of the i^{th} isotope in the chain; atoms/cm^3.
y = fission yield of the chain
F = fission rate (3.25×10^{10} fiss/sec = 1 watt)
λ_i = decay constant for i^{th} isotope

If T is the operating period of the reactor and t is the time measured from reactor shutdown, the activity of the various isotopes ($\lambda_i N_i$ = disintegration per unit time) per watt of reactor power is given by:

$$A_1 = \lambda_1 N_1 = yF(1-e^{-\lambda_1 T})\, e^{-\lambda_1 t} \quad dis/sec\text{-}watt$$

$$A_2 = \lambda_2 N_2 = yF\, \frac{\lambda_1 \lambda_2}{\lambda_2 - \lambda_1} \left[\frac{(1-e^{-\lambda_1 T})\, e^{-\lambda_1 t}}{\lambda_1} - \frac{(1-e^{-\lambda_2 T})\, e^{-\lambda t}}{\lambda_2} \right]$$

$$A_3 = \lambda_3 N_3 = yF\, \frac{\lambda_2 \lambda_3 (1-e^{-\lambda_1 T})\, e^{-\lambda_1 t}}{(\lambda_2-\lambda_1)(\lambda_3-\lambda_1)} + yF\, \frac{\lambda_1 \lambda_3 (1-e^{-\lambda_2 T})\, e^{-\lambda_2 t}}{(\lambda_1-\lambda_2)(\lambda_3-\lambda_2)} +$$

$$yF\, \frac{\lambda_1 \lambda_2 (1-e^{-\lambda_3 T})\, e^{-\lambda_3 t}}{(\lambda_1-\lambda_3)(\lambda_2-\lambda_3)}$$

In no chain was it necessary to consider more than three isotopes.

With the activities determined, the gamma power is obtained by multiplying the activity by the gamma energy emitted per disintegration. The gamma energies vary from kev to Mev. Ideally, for purposes of exposure calculations, each gamma energy should be considered individually, since the penetration is energy dependent and all contributions summed to obtain the total exposure. Because of the number of isotopes and gamma energies involved, this would require an impractical amount of calculation. Instead, the gamma energies are collected into nine energy groups, and average absorption characteristics are used for each group. The groups used areas follows:

Group	Energy Range (Mev)
I	0 to 0.1
II	0.1 to 0.2
III	0.2 to 0.4
IV	0.4 to 0.6
V	0.6 to 0.9
VI	0.9 to 1.35
VII	1.35 to 1.8
VIII	1.8 to 2.2
IX	2.2 to 2.6

The isotopes used in the study are listed in Table I. For purposes of comparison, the fission yields and branching ratios used in previous studies[3,4,5] are included. Fission yields generally were taken from NDA 27-39, although the lowest value was used in cases of disagreement. Since this study was not concerned with decay periods shorter than one day, many of the short-lived isotopes could be neglected.

The gamma power as a function of exposure period, T, and decay time, t, is shown in Fig. 6 through 9. In Fig. 10 the total computed gamma power is compared with the results of NDA 27-39 and with the Way - Wigner approximation.[6]

TABLE I
FISSION PRODUCT DATA

Isotope	NDA - 27 - 39			DOW - NR - 54002			Ashley - NAA			This Report		
	Yield	$t_{1/2}$	γ Mev %	Yield	$t_{1/2}$	γ Mev %	Yield	$t_{1/2}$	γ Mev	Yield	$t_{1/2}$	γ Mev %
Se 83	2.1×10^{-3} (N)	26 min	0.95 - (U)	5.8×10^{-3}	25 min	0.18 - 0.95						
Kr 83*				5.8×10^{-3}	114 min	0.041 - 100				5.8×10^{-3}	114 min	0.009 - 100
Br 84	6.5×10^{-3}	32 min	0.89 - 76	9.4×10^{-3}	30 min	1.89 - 18 1.89 - 18						
Kr 85*	1×10^{-2}	4.36 hr	0.15 - 85 0.3 - 15	1.4×10^{-2}	4.36 hr	0.15 - 77 0.31 - 23				1×10^{-2}	4.36 hr	0.15 - 77 0.31 - 23
Kr 85	3.17×10^{-3} (N)	10 yr	0.54 - 0.65	2.3×10^{-3}	10 yr	0.54 - 0.7	2.76×10^{-3}	9.4 yr	0.54 - 0.65	2.3×10^{-3}	10 yr	0.54 - 0.65
Rb 86	3.1×10^{-7} (N)	19.5 day	1.076 - 20	2×10^{-2}	19.5 day	1.08 - 20	3.1×10^{-7}	19.5 day	1.08 - 20	3.1×10^{-7}	19.5 day	1.08 - 20
Br 87	2×10^{-2} (N)	57.1 sec	5.4 - 0.5									
Kr 87	2×10^{-2} (N)	78 min	0.41 - 25 1.89 - 25 2.3 - 25	2.6×10^{-2}	78 min	0.41 - 13 1.89 - 13 2.3 - 13	2.3×10^{-2}	78 min	1.89 - 13 2.3 - 13	2.0×10^{-2}	78 min	0.41 - 25 1.89 - 25
Kr 88	3.1×10^{-2}	2.77 hr	1.8 - 80 2.18 - 8 0.38 6.8	3.3×10^{-2}	2.77 hr	0.028 - 68				3.1×10^{-2}	2.77 hr	.028 - 68
Rb 88	3.1×10^{-2}	17.7 min	0.9 - 8 1.86 - 21 2.8 - 1	3.3×10^{-2}	17.8 min	0.9 - 8 1.86 - 13 2.8 - 1	3.1×10^{-2}	17.8 min	0.9 - 8 1.86 - 21 2.8 - 1	3.1×10^{-2}	17.7 min	0.9 - 8 1.86 - 21 2.8 - 1
Rb 89	4.6×10^{-2} (N)	15.4 min	(U) - (U)	4×10^{-2}	15.4 min	1.0 - 100	4.8×10^{-2}	15.4 min	0.7 - 100			
Sr 91	5×10^{-2}	9.7 hr	0.64 - 26 0.747 - 14 0.66 - 15 1.03 - 33 1.41 - 7	5.4×10^{-2}	9.7 hr	0.64 - 26 0.66 - 15 0.75 - 15 1.03 - 33 1.40 - 7	5×10^{-2}	9.7 hr	0.64 - 67 0.66 - 23 0.75 - 6 1.03 - 33 1.41 - 7	5×10^{-2}	9.7 hr	0.64 - 11 0.66 - 22 0.75 - 7 1.03 - 33 1.41 - 7
Y 91*	2.3×10^{-3}	51 min	0.55 - 100	5.4×10^{-2}	51 min	0.55 - 48	1.8×10^{-2}	51 min	0.55 - 100	2×10^{-2}	51 min	0.55 - 100
Y 91	5.9×10^{-2}	61 day	0.2 - 0.1 1.2 - 0.1				5.3×10^{-2}	61 day	1.2 - 0.1			
Sr 92				5.8×10^{-2}	2.7 hr	1.0 - 100						
Y 92	5×10^{-2}	3.6 hr	8.7 - (U)	5.8×10^{-2}	3.6 hr	0.6 - 100						
Sr 93				6.2×10^{-2}	7 min	1.0 - 100						
Y 93	6×10^{-2}	10 hr	0.7 - 10	6.2×10^{-2}	10 hr	0.7 - 100	6×10^{-2}	10 hr	0.7 - 100	6×10^{-2}	10 hr	0.7 - 100
Y 94	5×10^{-2}	16.5 min	1.4 - 10	6.3×10^{-2}	16.5 min	1.4 - 100	6.2×10^{-2}	16.5 min	1.4 - 100			
Zr 95	6×10^{-2}	65 day	0.725 - 49 0.756 - 49 0.235 - 2	6.4×10^{-2}	65 day	0.72 - 99	6.2×10^{-2}	65 day	0.72 - 99	6×10^{-2}	65 day	0.72 - 99
Nb 95*	6×10^{-4}	90 hr	0.23 - 100	6.4×10^{-2}	90 hr	0.23 - 1				6×10^{-4}	90 hr	0.23 - 100
Nb 95	6×10^{-2}	35 day	0.765 - 100	6.4×10^{-2}	35 day	0.758 - 100	6×10^{-2}	35 day	0.765 - 100	6×10^{-2}	35 day	0.765 - 100

TABLE I (Continued)

TABLE I (Continued)

Isotope	NDA - 27 - 39			DOW - NR - 54002			Ashley - NAA			This Report		
	Yield	$t_{1/2}$	γ Mev %	Yield	$t_{1/2}$	γ Mev %	Yield	$t_{1/2}$	γ Mev %	Yield	$t_{1/2}$	γ Mev %
Zr 97	6.2×10^{-2} (N)	17 hr	0	6.1×10^{-2}	17 hr	0				6×10^{-2}	17 hr	0
Nb 97*	6.2×10^{-2}	60 sec	0.75 - 100	6.1×10^{-2}	60 sec	0.75 - 100	6.2×10^{-2}	60 sec	0.75 - 100	6.2×10^{-2}	60 sec	0.75 - 100
Nb 97	6.2×10^{-2}	72.1 min	0.67 - 100	6.1×10^{-2}	72.1 min	0.665 - 100	6.2×10^{-2}	72 min	0.67 - 100	6.2×10^{-2}	72.1 min	0.665 - 100
Mo 99	6.2×10^{-2}	68.3 hr	0.14 - 100 0.73 - 13	6.1×10^{-2}	67 hr	0.18 - 98 0.74 - 18 0.78 - 2	6.2×10^{-2}	67 hr	0.75 - 13	6.2×10^{-2}	67 hr	0.04 - 97.5 0.37 - 1.5 0.74 - 17.5 0.78 - 2.5
Tc 99*	5.5×10^{-2} (N)	6.04 hr	0.14 - 100	6.1×10^{-2}	6.04 hr	0.14 - 2				6.2×10^{-2}	6.04 hr	0.14 - 100
Mo 101	5×10^{-2} (N)	14.6 min	0.7 - (U) 0.96 - (U)	5.6×10^{-2}	14.6 min	0.19 - 100 0.96 - 70						
Tc 101	5×10^{-2} (N)	16.5 min	0.31 - 95	5.6×10^{-2}	14 min	0.31 - 100						
Ru 103	3.7×10^{-2}	39.8 day	0.494 - 94	1.9×10^{-2}	39.8 day	0.50 - 99	3.7×10^{-2}	40 day	0.5 - 92	3.7×10^{-2}	39.8 day	0.498 - 100 0.05 - 99
Ru 105	9×10^{-3}	4.5 hr	0.726 - 100	4×10^{-3}	4.5 hr	0.726 - 100	9×10^{-3}	4.5 hr	0.726 - 100	9×10^{-3}	4.5 hr	0.726 - 100
Rh 105*	(U) (N)	45 sec	0.13 - 100	4×10^{-3}	45 sec	0.13 - 100						
Rh 105	9×10^{-3} (N)	36.5 hr	0.32 - 5	4×10^{-3}	36.5 hr	0.32 - 5				9×10^{-3}	36.5 hr	0.32 - 5
Ru 106	5.2×10^{-3} (N)	1 yr								5.2×10^{-3}	1 yr	0
Ru 106	5.2×10^{-3}	30 sec	0.513 - 24 0.624 - 12 0.87 - 1 1.05 - 2 1.55 - 1 2.41 - 0.2				3.3×10^{-3}	30 sec	0.51 - 24 0.62 - 12 0.87 - 1 1.04 - 2 1.55 - 1 2.42 - (U)	5.2×10^{-3}	30 sec	0.51 - 24
Pd 109										2.8×10^{-3}	13.6 hr	0
Ag 109*										5.2×10^{-3}	30 sec	0.087 - 100
Pd 111*		5.5 hr	1.77 - (U)				1.8×10^{-5}	5.5 hr	1.77 - 25			
Pd 111	1.8×10^{-4} (N)	22 min	0.4 - 0.7 (U)									
Ag 111	1.8×10^{-4} (N)	7.6 day	0.243 - 1 0.34 - 6.5							1.8×10^{-4}	7.6 day	0.24 - 1 0.34 - 6
Ag 112	8.3×10^{-5} (N)	3.2 hr	0.6 - 1.4 (U)									
Cd 115*	8×10^{-6} (N)	43 day	0.48 - 0.5 0.94 - 1.2 1.30 - 0.8				1×10^{-5}	43 day	0.50 - 0.1 0.94 - 1.4 1.30 - 0.4			
Cd 115	1.1×10^{-4} (N)	53 hr	0.525 - 42 0.335 - 100				1×10^{-4}	53 hr				
In 117	1×10^{-4} (N)	2.5 hr	0.16 - 0.94									
In 118	1×10^{-4} (N)	4.5 min	(U)									
Sn 123	1.6×10^{-4} (N)	40 min	0.15 - (U)									
Sn 125	2×10^{-4} (N)	9.5 min	1.37 - 1							(U)		

TABLE I (Continued)

Isotope	NDA - 27 - 39			DOW - NR - 54002			Ashley - NAA			This Report		
	Yield	$t_{1/2}$	γ Mev %	Yield	$t_{1/2}$	γ Mev %	Yield	$t_{1/2}$	γ Mev %	Yield	$t_{1/2}$	γ Mev %
Sn 125							2.2×10^{-4}	94 day	1.90 - 5	(U)		
Sb 125	(U) (N)	2.7 yr	0.17 - 18 0.43 - 49 0.61 - 33				2.2×10^{-4}	2.7 yr	0.60 - 33	2×10^{-4}	2.7 yr	0.035 - 82 0.172 - 17 0.431 - 66 0.602 - 16
Te 125*										2×10^{-4}	58 day	0.035 - 100 0.11 - 100
Sb 126	1×10^{-3} (N)	9 hr	0.9 - (U) 0.4 - (U)				9×10^{-4}	9 hr	0.9 - 100	1×10^{-3}	9 hr	0.4 - 100
Sb 127	9.4×10^{-4}	93 hr	0.72 - (U)				1.2×10^{-3}	93 hr	0.72 - 16	9.4×10^{-4}	93 hr	0.72 - 100
Sb 129	(N)			6.6×10^{-3}	4.2 hr	1.0 - 100						
Te 129*	1.9×10^{-3}	33.5 day	0.11 - 100	6.6×10^{-3}			4.4×10^{-3}	33.5 day	0.106 - 100	(U)*	33.5 day	
Te 129	1.0×10^{-3}	72 min	0.3 - 10	6.6×10^{-3}	72 min	0.3 - 100 0.8 - 100	1.9×10^{-3}	72 min	0.3 - (U)	1.9×10^{-3}	72 min	0.3 - 100
Te 131*	4.4×10^{-3}	30 hr	0.17 - 100	3.2×10^{-2}	30 hr	0.18 - 100	4.4×10^{-3}	30 hr	0.18 - 100	4.4×10^{-3}	30 hr	0.18 - 100
Te 131	2.8×10^{-2}	24.8 min	0.7 - 45 0.16 - 100	3.2×10^{-2}	24.8 min	0.16 - 100 0.7 - 45	3×10^{-2}	24.8 min	0.64 - 35 2.23 - 22	4.4×10^{-3}	24.8 min	0.16 - 100 0.64 - 45
I 131	2.8×10^{-2}	8.14 day	0.163 - 0.7 0.284 - 2.2 0.364 - 85 0.637 - 9.3 0.722 - 2.8	3.2×10^{-2}	8.14 day	0.08 - 5 0.28 - 5 0.364 - 82 0.637 - 9.3 0.722 - 2.8	3×10^{-2}	8.14 day	0.637 - 9.3 0.722 - 2.8	2.8×10^{-2}	8.14 day	0.08 - 2.2 0.163 - 0.7 0.284 - 5.3 0.364 - 80 0.637 - 9
Te 132	3.4×10^{-2}	77.7 hr	0.23 - 1	4.7×10^{-2}	77.7 hr	0.23 - 100				3.4×10^{-2}	77.7 hr	0.23 - 100
I 132	4.4×10^{-2}	2.4 hr	0.69 - 88 1.41 - 10 2.0 - 2	4.7×10^{-2}		0.69 - 88 1.41 - 9.5 2.0 - 2.5	3.4×10^{-2}	2.4 hr	0.69 - 49 1.41 - 49 2.0 - 2.7	3.4×10^{-2}	2.4 hr	0.60 - 96 1.4 - 11 2.0 - 2.6
Te 133*	(U) (N)	63 min	0.4 - 100	6.4×10^{-2}	63 min	0.4 - 100						
Te 133	4.5×10^{-2} (N)	2 min	0.6 - 100 1.0 - 70	6.4×10^{-2}	2 min	0.6 - 100 1.0 - 70	5×10^{-2}	2 min	0.6 - 100 1.0 - 70			
I 133	4.6×10^{-2}	20.8 hr	0.53 - 94 0.85 - 5 1.4 - 1	6.4×10^{-2}	20.5 hr	0.53 - 94 0.85 - 5 1.4 - 1	5×10^{-2}	20.5 hr	0.53 - 94 0.85 - 5 1.4 - 1	4.6×10^{-2}	20.8 hr	0.53 - 94 0.85 - 5 1.4 - 1
Xe 133*				6.4×10^{-2}	2.3 day	0.233 - 100				4.6×10^{-2}	2.3 day	0.233 - 100
Xe 133				6.4×10^{-2}	5.27 day	0.08 - 100				4.6×10^{-2}	5.27 day	0.08 - 100
Te 134				7.8×10^{-2}	44 min	1.0 - 100						
I 134	5.7×10^{-2}	52.5 min	1.2 - 30 2.2 - 1	7.8×10^{-2}	52.5 min	2.5 - 1	5.7×10^{-2}	52.5 min	1.2 - 70 2.3 - 1			
I 135	5.9×10^{-2}	6.68 hr	1.3 - 90 1.6 - 4 2.4 - 2	6.3×10^{-2}	6.68 hr	1.8 - 4 2.4 - 2	6×10^{-2}	6.68 hr	1.3 - 25 1.6 - 76 2.4 - 1.1	5.9×10^{-2}	6.68 hr	1.3 - 25 1.6 - 4 1.88 - 34

TABLE I (Continued)

Isotope	NDA - 27 - 39			DOW - NR - 54002			Ashley - NAA			This Report		
	Yield	$t_{1/2}$	γ Mev %	Yield	$t_{1/2}$	γ Mev %	Yield	$t_{1/2}$	γ Mev %	Yield	$t_{1/2}$	γ Mev %
Sn 125							2.2×10^{-4}	94 day	1.90 - 5	(U)		
Sb 125	(U) (N)	2.7 yr	0.17 - 18 0.43 - 49 0.61 - 33				2.2×10^{-4}	2.7 yr	0.60 - 33	2×10^{-4}	2.7 yr	0.035 - 82 0.172 - 17 0.431 - 66 0.602 - 16
Te 125*										2×10^{-4}	58 day	0.035 - 100 0.11 - 100
Sb 126	1×10^{-3} (N)	9 hr	0.9 - (U) 0.4 - (U)				9×10^{-4}	9 hr	0.9 - 100	1×10^{-3}	9 hr	0.4 - 100
Sb 127	9.4×10^{-4}	93 hr	0.72 - (U)				1.2×10^{-3}	93 hr	0.72 - 16	9.4×10^{-4}	93 hr	0.72 - 100
Sb 129	(N)			6.6×10^{-3}	4.2 hr	1.0 - 100						
Te 129*	1.9×10^{-3}	33.5 day	0.11 - 100	6.6×10^{-3}			4.4×10^{-3}	33.5 day	0.106 - 100	(U)*	33.5 day	
Te 129	1.0×10^{-3}	72 min	0.3 - 10	6.6×10^{-3}	72 min	0.3 - 100 0.8 - 100	1.9×10^{-3}	72 min	0.3 - (U)	1.9×10^{-3}	72 min	0.3 - 100
Te 131*	4.4×10^{-3}	30 hr	0.17 - 100	3.2×10^{-2}	30 hr	0.18 - 100	4.4×10^{-3}	30 hr	0.18 - 100	4.4×10^{-3}	30 hr	0.18 - 100
Te 131	2.8×10^{-2}	24.8 min	0.7 - 45 0.16 - 100	3.2×10^{-2}	24.8 min	0.16 - 100 0.7 - 45	3×10^{-2}	24.8 min	0.64 - 35 2.23 - 22	4.4×10^{-3}	24.8 min	0.16 - 100 0.64 - 45
I 131	2.8×10^{-2}	8.14 day	0.163 - 0.7 0.284 - 2.2 0.364 - 85 0.637 - 9.3 0.722 - 2.8	3.2×10^{-2}	8.14 day	0.08 - 5 0.28 - 5 0.364 - 82 0.637 - 9.3 0.722 - 2.8	3×10^{-2}	8.14 day	0.637 - 9.3 0.722 - 2.8	2.8×10^{-2}	8.14 day	0.08 - 2.2 0.163 - 0.7 0.284 - 5.3 0.364 - 80 0.637 - 9
Te 132	3.4×10^{-2}	77.7 hr	0.23 - 1	4.7×10^{-2}	77.7 hr	0.23 - 100				3.4×10^{-2}	77.7 hr	0.23 - 100
I 132	4.4×10^{-2}	2.4 hr	0.69 - 88 1.41 - 10 2.0 - 2	4.7×10^{-2}		0.69 - 88 1.41 - 9.5 2.0 - 2.5	3.4×10^{-2}	2.4 hr	0.69 - 49 1.41 - 49 2.0 - 2.7	3.4×10^{-2}	2.4 hr	0.60 - 96 1.4 - 11 2.0 - 2.6
Te 133*	(U) (N)	63 min	0.4 - 100	6.4×10^{-2}	63 min	0.4 - 100						
Te 133	4.5×10^{-2} (N)	2 min	0.6 - 100 1.0 - 70	6.4×10^{-2}	2 min	0.6 - 100 1.0 - 70	5×10^{-2}	2 min	0.6 - 100 1.0 - 70			
I 133	4.6×10^{-2}	20.8 hr	0.53 - 94 0.85 - 5 1.4 - 1	6.4×10^{-2}	20.5 hr	0.53 - 94 0.85 - 5 1.4 - 1	5×10^{-2}	20.5 hr	0.53 - 94 0.85 - 5 1.4 - 1	4.6×10^{-2}	20.8 hr	0.53 - 94 0.85 - 5 1.4 - 1
Xe 133*				6.4×10^{-2}	2.3 day	0.233 - 100				4.6×10^{-2}	2.3 day	0.233 - 100
Xe 133				6.4×10^{-2}	5.27 day	0.08 - 100				4.6×10^{-2}	5.27 day	0.08 - 100
Te 134				7.8×10^{-2}	44 min	1.0 - 100						
I 134	5.7×10^{-2}	52.5 min	1.2 - 30 2.2 - 1	7.8×10^{-2}	52.5 min	2.5 - 1	5.7×10^{-2}	52.5 min	1.2 - 70 2.3 - 1			
I 135	5.9×10^{-2}	6.68 hr	1.3 - 90 1.6 - 4 2.4 - 2	6.3×10^{-2}	6.68 hr	1.8 - 4 2.4 - 2	6×10^{-2}	6.68 hr	1.3 - 25 1.6 - 76 2.4 - 1.1	5.9×10^{-2}	6.68 hr	1.3 - 25 1.6 - 4 1.88 - 34

TABLE 1 (Continued)

Isotope	NDA - 27 - 39			DOW - NR - 58888			Ashley - NAA			This Report		
	Yield	$t_{1/2}$	γMev %	Yield	$t_{1/2}$	γMev %	Yield	$t_{1/2}$	γMev%	Yield	$t_{1/2}$	γMev %
Xe 135[a]	1.8×10^{-2} (N)	13 min	0.52 - 100	6.3×10^{-2}	15.6 min	0.52 - 6	2×10^{-2}	15.6 min	0.52 - 100	5.9×10^{-2}	13 min	0.50 - 100
Xe 135	5.9×10^{-2}	9.13 hr	0.25 - 100	6.3×10^{-2}	9.13 hr	0.25 - 100				5.9×10^{-2}	9.13 hr	0.25 - 100
Cs 136	6.2×10^{-5}	13.7 day	1.2 - 10	5.9×10^{-2}	13.7 day	1.2 - 100	6.1×10^{-2}	13.7 day	1.2 - 100	6.2×10^{-5}	13.7 day	0.9 - 100
Cs 137	5.7×10^{-2}	30 yr	0.66 - 92							6.2×10^{-2}	30 yr	0.66 - 92
Cs 138	6×10^{-2}	32 min	0.46 - 33 0.98 - 63 1.44 - 100	6×10^{-2}	329 min	0.46 - 67 0.98 - 33 1.44 - 100	6.3×10^{-2}	329 min	1.44 - 100	6.0×10^{-2}	32 min	1.44 - 100
Ba 139	6.3×10^{-2}	85 min	0.16 - 26	6.4×10^{-2}	85 min	0.16 - 26 1.05 - 0.6	6.2×10^{-2}	85 min	0.16 - 26 1.05 - 0.6	6.3×10^{-2}	85 min	0.16 - 26 1.05 - 0.6
Ba 140	6.2×10^{-2}	12.8 day	0.16 - 70 0.30 - 10 0.54 - 30	6.3×10^{-2}	12.8 day	0.16 - 70 0.30 - 10 0.54 - 30	6.2×10^{-2}	12.8 day	0.16 - 70 0.30 - 10 0.54 - 30	6.2×10^{-2}	12.8 day	0.03 - 100 0.16 - 70 0.31 - 10 0.54 - 30
La 140	6.2×10^{-2}	40.2 hr	0.33 - 5 0.49 - 36 0.82 - 26 1.6 - 94 2.5 - 5	6.3×10^{-2}	40.0 hr	0.09 - 1 0.33 - 3 0.49 - 22 0.82 - 16 1.60 - 56 2.50 - 3 3.0 - 1	6.2×10^{-2}	40.0 hr	0.33 - 10 0.49 - 30 0.82 - 55 1.60 - 95 2.50 - 5 2.9 - 0.1	6.2×10^{-2}	40.2 hr	0.09 - 64 0.33 - 10 0.49 - 30 0.82 - 54 1.6 - 95
Ba 141	4.6×10^{-2} (N)	18 min	(U)	6×10^{-2}	18 min	1.0 - 100						
La 141	4.6×10^{-2} (N)	3.7 hr	1.6 - 5	6×10^{-2}	3.7 hr	1.5 - 5	4.6×10^{-2}	3.7 hr	1.5 - 5	4.6×10^{-2}	3.7 hr	1.5 - 5
Ce 141	5.7×10^{-2}	32.5 day	0.15 - 67	6×10^{-2}	33.1 day	0.15 - 67	4.6×10^{-2}	32.5 day	0.15 - 67	4.6×10^{-2}	32.5 day	0.15 - 67
La 142	5.5×10^{-2} (N)	77 min	(U)	5.6×10^{-2}	74 min	1.0 - 100						
Ce 143	5.4×10^{-2}	34 hr	0.28 - 40 0.70 - 30	4.9×10^{-2}	33 hr	0.29 - 70 0.66 - 15 0.72 - 15 1.0 - 100	3.8×10^{-2}	33 hr	0.28 - 40 0.70 - 30	5.4×10^{-2}	34 hr	0.035 - 100 0.29 - 70 0.36 - 30
Ce 144	5.3×10^{-2} (N)	275 day	0.134 - 20	4.2×10^{-2}	282 day	0.03 - 10 0.08 - 10 0.10 - 10 0.134 - 10	4.6×10^{-2}	282 day	0.03 - 10 0.05 - 10 0.08 - 10 0.10 - 10	5.3×10^{-2}	295 day	0.081 - 3 0.134 - 22
								17.5 min	0.134 - 10			
Pr 144	4.6×10^{-2}	17.5 min	0.695 - 0.5 2.18 - 0.5 1.48 - 0.2	4.2×10^{-2}	17.5 min	0.696 - 1 2.19 - 1	4.6×10^{-2}	17.5 min	0.696 - 0.5 1.5 - 0.2 2.19 - 0.5	5.3×10^{-2}	17.5 min	0.695 - 1.25 1.49 - 0.5 2.18 - 1.4
Pr 146	2.8×10^{-2} (N)	24 min	0.49 - (U) 0.78 - (U)	2.8×10^{-2}	24 min	0.49 - 100 0.78 - 100						
Nd 147	2.6×10^{-2}	11.6 day	0.30 - 5 0.39 - 10 0.52 - 25	2.2×10^{-2}	11.3 day	0.09 - 60 0.32 - 15 0.53 - 25				2.6×10^{-2}	11.6 day	0.09 - 75 0.23 - 15 0.53 - 25
Nd 149	1.6×10^{-2} (N)	1.8 hr	(U)	1.1×10^{-2}	2.0 hr	0.15 - 5 0.40 - 15 0.55 - 5						
Pm 149	1.3×10^{-2} (N)	54 hr	0.29 - (U) 1.3 - (U)	1.1×10^{-2}	54 hr	0.29 - 99 1.3 - 1				1.3×10^{-2}	54 hr	0.29 - 100
Pm 151	4.5×10^{-3}	27.5 hr	(U)									
Sm 153	1.9×10^{-3}	47 hr	0.104 - 33 0.53 - 0.07 0.60 - 0.03							1.9×10^{-3}	47 hr	0.07 - 19 0.104 - 81
Eu 155	3.1×10^{-4}	1.7 yr	0.1 - 80							3.1×10^{-4}	1.7 yr	0.087 - 80 0.106 - 100
Eu 156	1.3×10^{-4}	15.4 day	2.0 - 60							1.3×10^{-4}	15.4 day	2.0 - 68
Eu 157	7×10^{-5} (N)	15.4 hr	0.6 - 75 0.2 - 75							7×10^{-5}	15.4 hr	0.6 - 75 0.2 - 75

a. (N) denotes gamma energy listed but neglected; (U) refers to uncertainty.

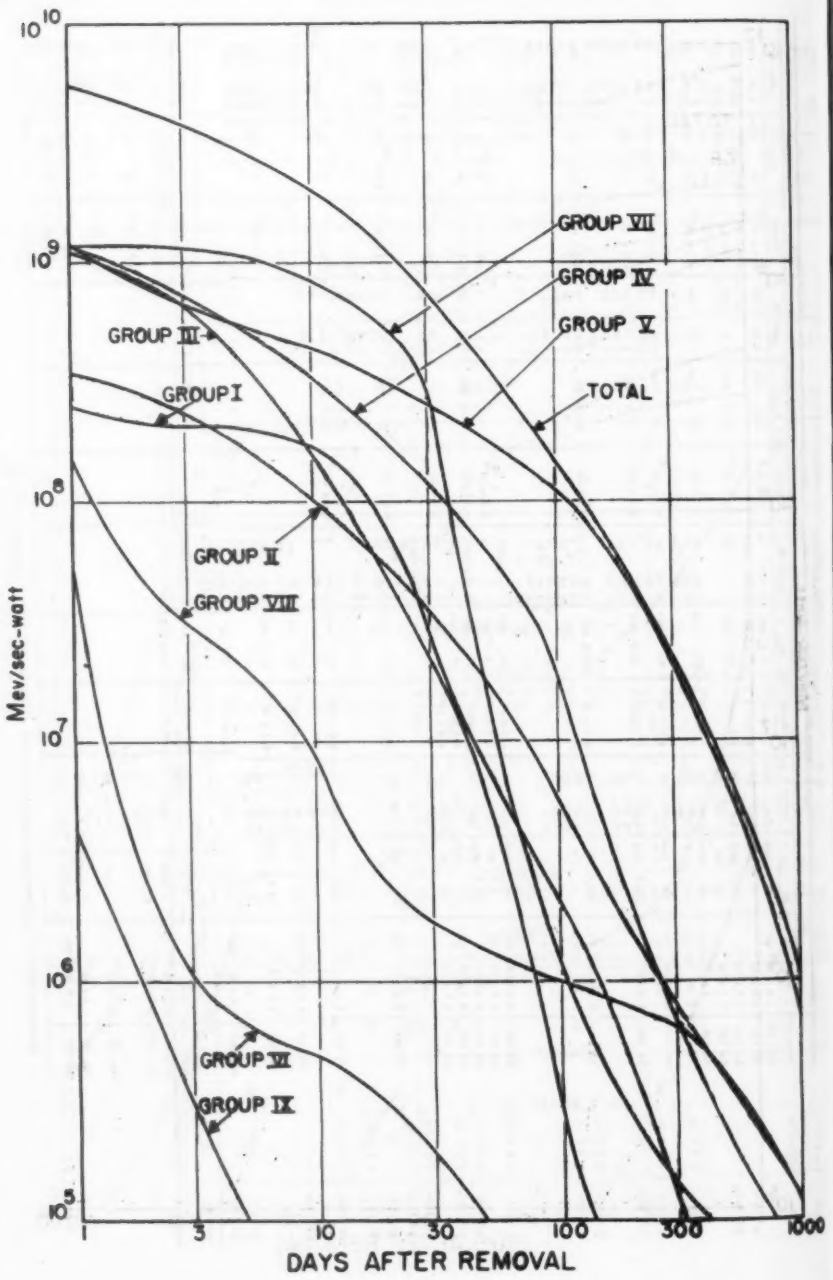


Fig. 6. Fission Product Gamma Power - 10 Day Exposure Period

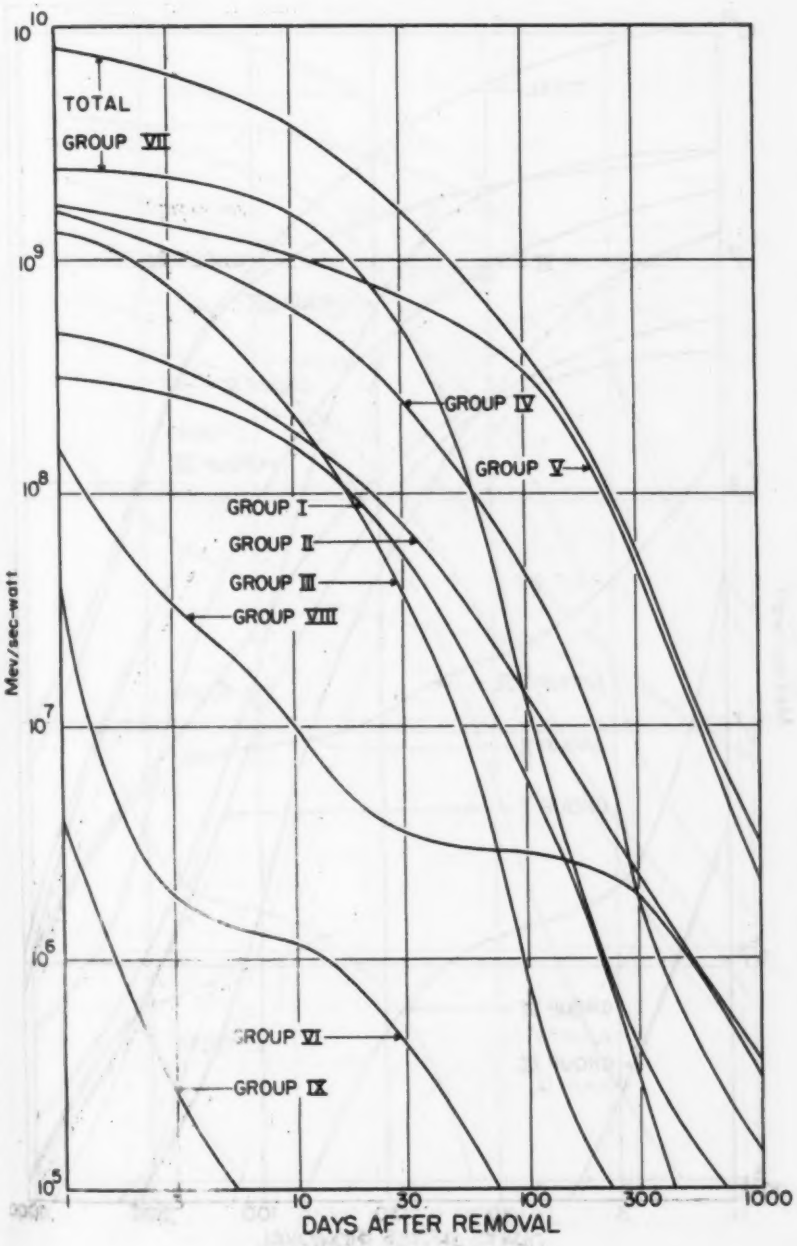


Fig. 7. Fission Product Gamma Power - 30 Day Exposure Period

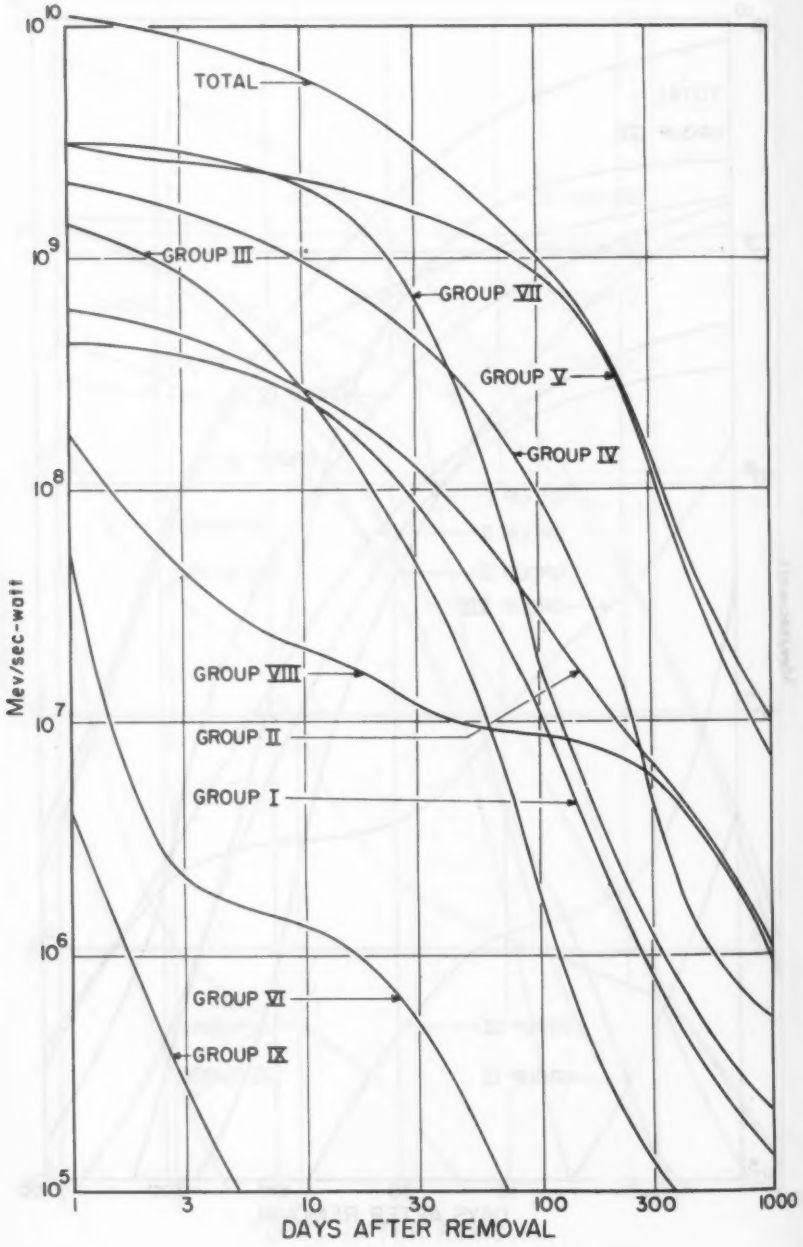


Fig. 8. Fission Product Gamma Power - 100 Day Exposure Period

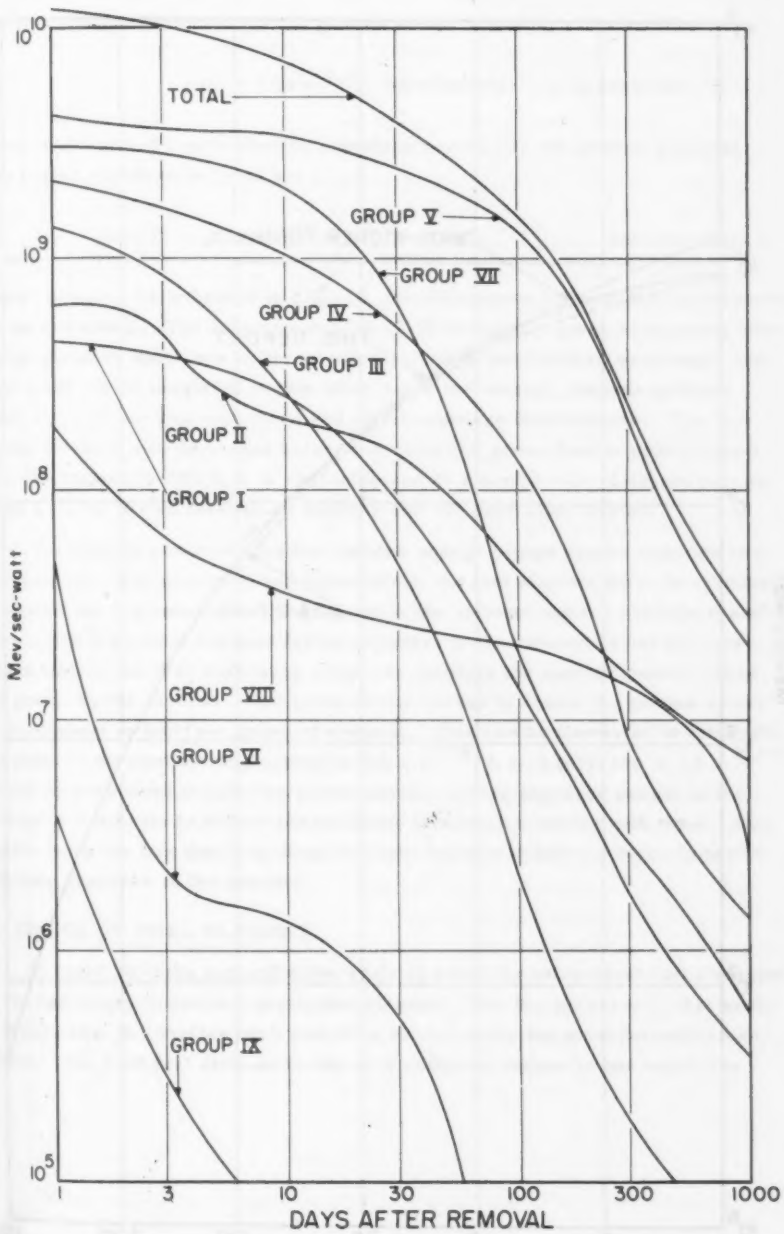


Fig. 9. Fission Product Gamma Power - 300 Day Exposure Period

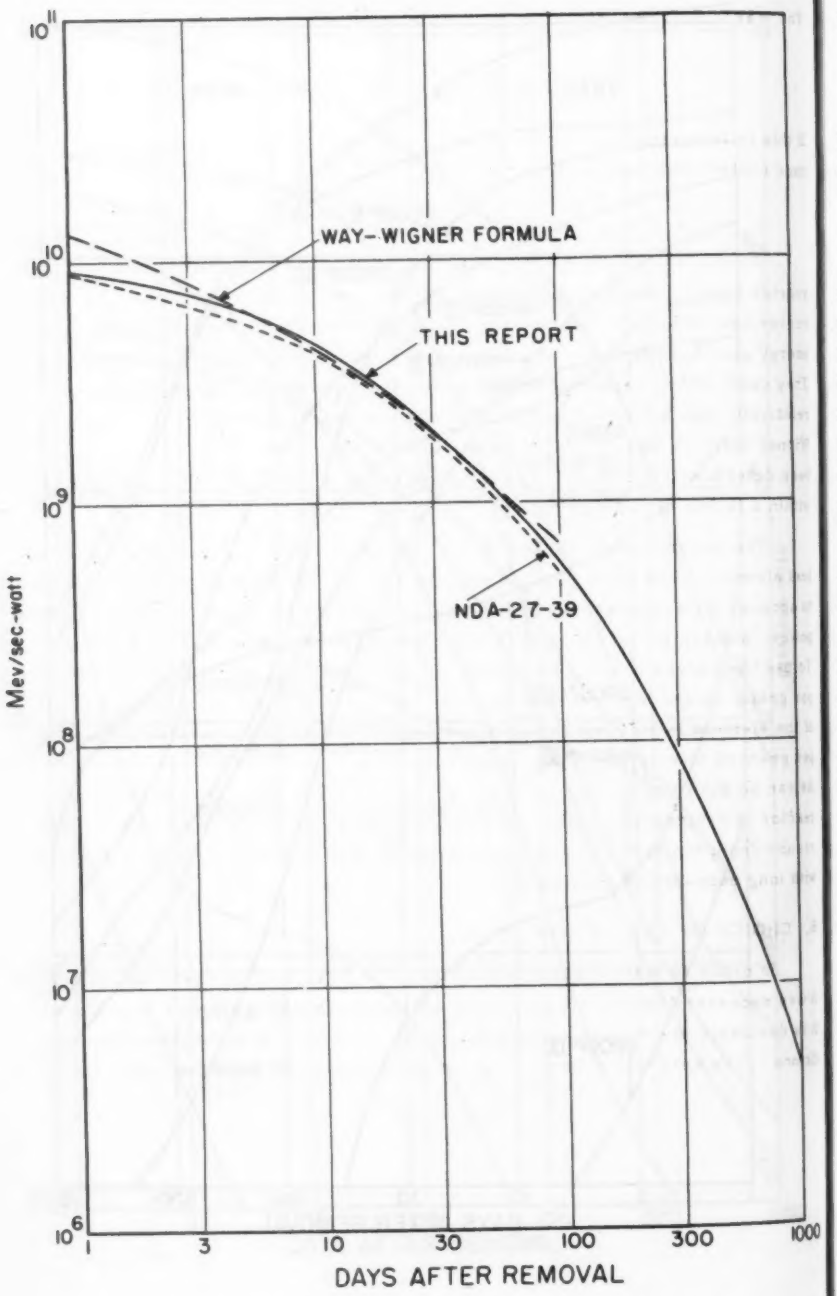


Fig. 10. Comparison of Fission Product Gamma Power - Exposure Period 40 Days

The Way - Wigner formula for the gamma power following a fission burst is:

$$g(t) = 1.26\, t^{-1.2} \quad \text{Mev/sec-fiss} \quad (t \text{ in seconds})$$

If this is integrated over a reactor operating period, T, the gamma power at time t after shutdown is given by:

$$G(t, T) = 2.11 \times 10^{10} \left[t^{-0.2} - (t + T)^{-0.2} \right] \quad \text{Mev/sec-watt of}$$

reactor power. As indicated in Fig. 10, the differences between the two calculated curves are small. The curve from NDA 27-39 is slightly lower since many low-energy gammas which are unimportant in shielding calculations were neglected. They could not be neglected in this study since low-energy gammas produce relatively high surface exposures and affect exposure distributions. The Way - Wigner formula was developed before the nature of gross fission products had been determined in detail; it is characterized as a useful rule-of-thumb correct within a factor of two between 10 seconds and 100 days after fission.

The gamma power curves for the nine energy groups can be used for any fuel element. The geometry and materials of the fuel element must be specified to account for self-absorption of gammas in the element and the average specific power, watts/gm-fuel element during exposure in the reactor, must be known. To use the curves it is necessary simply to multiply the specific power, watts per gram, by the Mev/sec-watt given by the curves to obtain the gamma power of the element in Mev/sec-gram of element. This can be converted to kilowatts per gram of element by multiplying by 1.6×10^{-16}; i.e. 1 Mev/sec = 1.6×10^{-16} kw. As can be seen from the gamma power curves, a long exposure period in the reactor is desirable to reduce the variation in source intensity with time. This results from the fact that long-lived isotopes become relatively more important with long exposure in the reactor.

B. CHOICE OF FUEL ELEMENT

In order to make a quantitative study of a facility using spent fuel elements, it was necessary to select a particular element. For the purposes of this study it is desirable to consider each radiation source under the most favorable conditions. The best fuel element to use as a radiation source is one which has

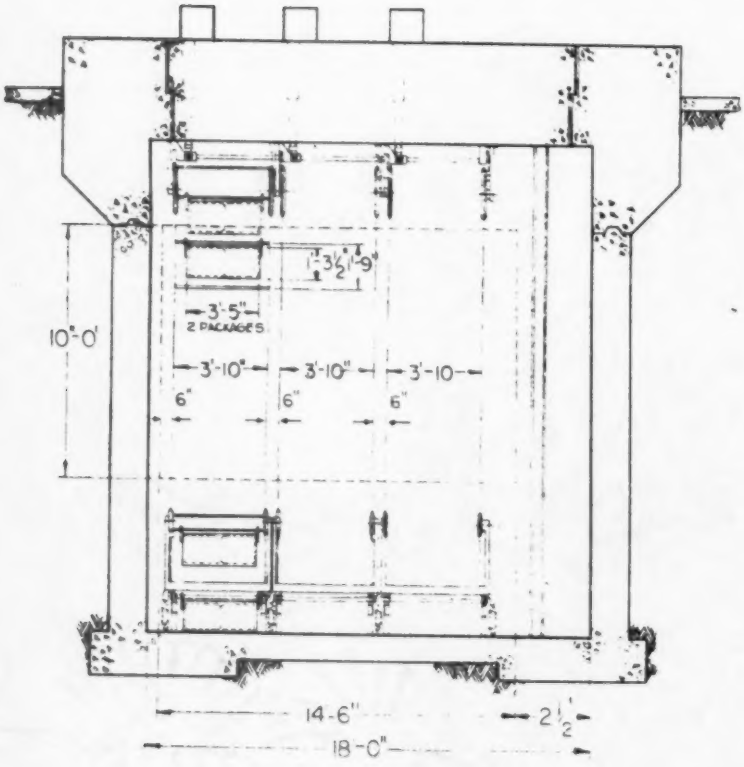
undergone continuous exposure in the reactor for a long period of time at a high specific power. This type of element will provide the most intense source and will show the least variation in intensity with time.

The class of reactors meeting these conditions best are those designed for stationary power-plant applications. There are no such reactors operating in this country at the present time. However, under the AEC reactor development program, several have been designed and some are under construction. In most of these designs the fuel element consists of a series of rods or plates, welded or mechanically fastened into a cluster. Typical of these, and having the advantage of being capable of mechanical disassembly, is the fuel element proposed for a sodium-graphite power reactor. This element consists of a symmetrical cluster of 19 rods, 10 feet long and contained in a 0.5-inch diameter stainless-steel tube with a 0.010-inch wall.

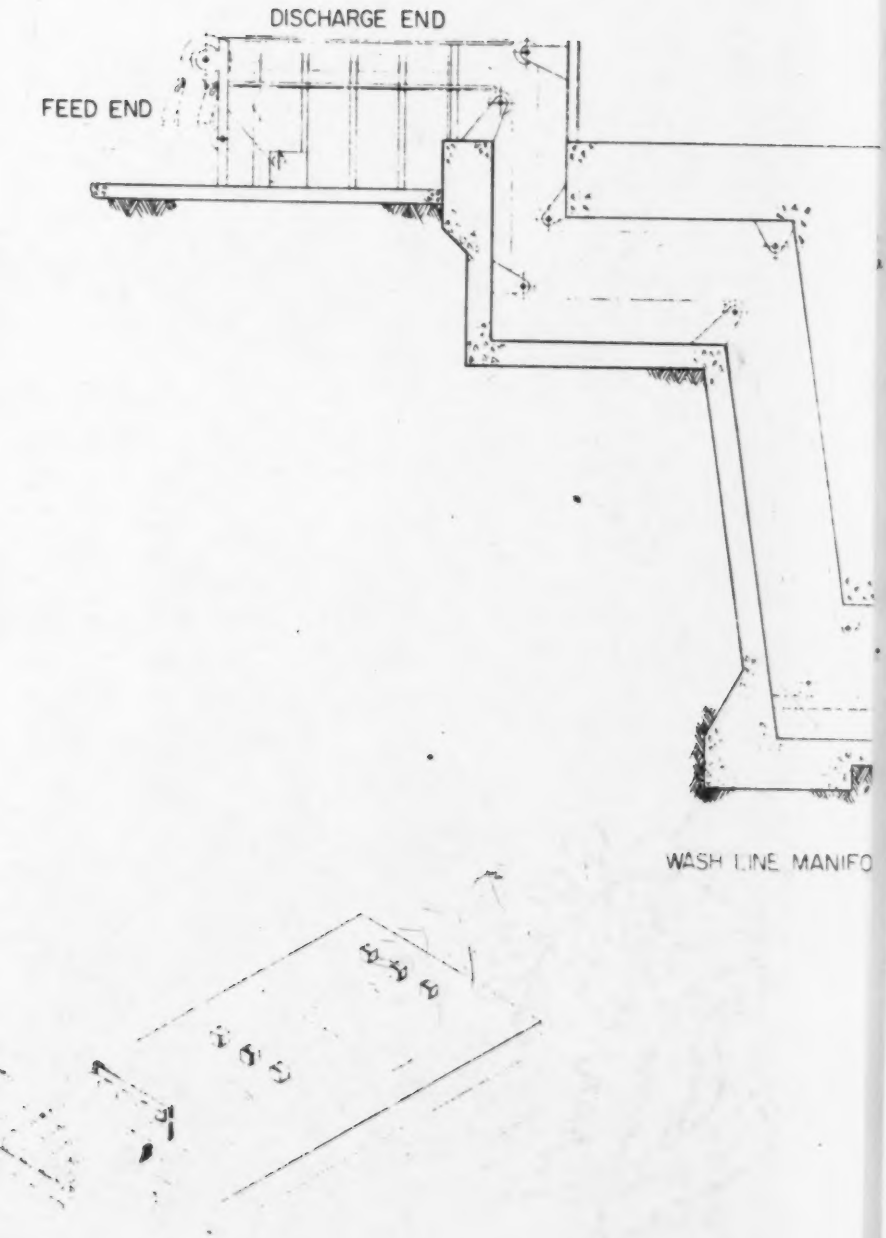
Preliminary designs were obtained for two food radiation facilities using this element - one uses the individual rods, the other the entire cluster. The fraction of gamma power which escapes the individual rod varies from 41 to 45 per cent depending upon the time after removal from the reactor; the corresponding fraction for the 19-rod cluster is 20 per cent. Because of this difference in self-absorption the first design was made for use of the individual rods. The cost of handling equipment required for dismantling the cluster was sufficiently high to warrant a new preliminary design for use of the cluster. The latter facility is less expensive per unit of output, and is the one presented in this report.

C. FUEL ELEMENT HANDLING

In removing the spent fuel from the sodium graphite reactor, a fuel-handling "coffin" is lowered over the shield plug from which the fuel element is suspended. A gas-tight seal is made to protect the sodium coolant in the reactor. The shield plug, with the attached fuel element, is pulled into the coffin and a new unit inserted. The seal is broken between the handling coffin and the reactor shield. The spent fuel element, in a helium atmosphere in the coffin, is transferred to a washing area to remove sodium which clings to the cluster. The wash water is monitored to detect possible leaks in the stainless-steel cladding of the fuel element. In normal operation, the element would then be transferred to a storage area for cooling prior to chemical processing.



FEED


DISCHARGE END
FEED END
WASH LINE MANIFO

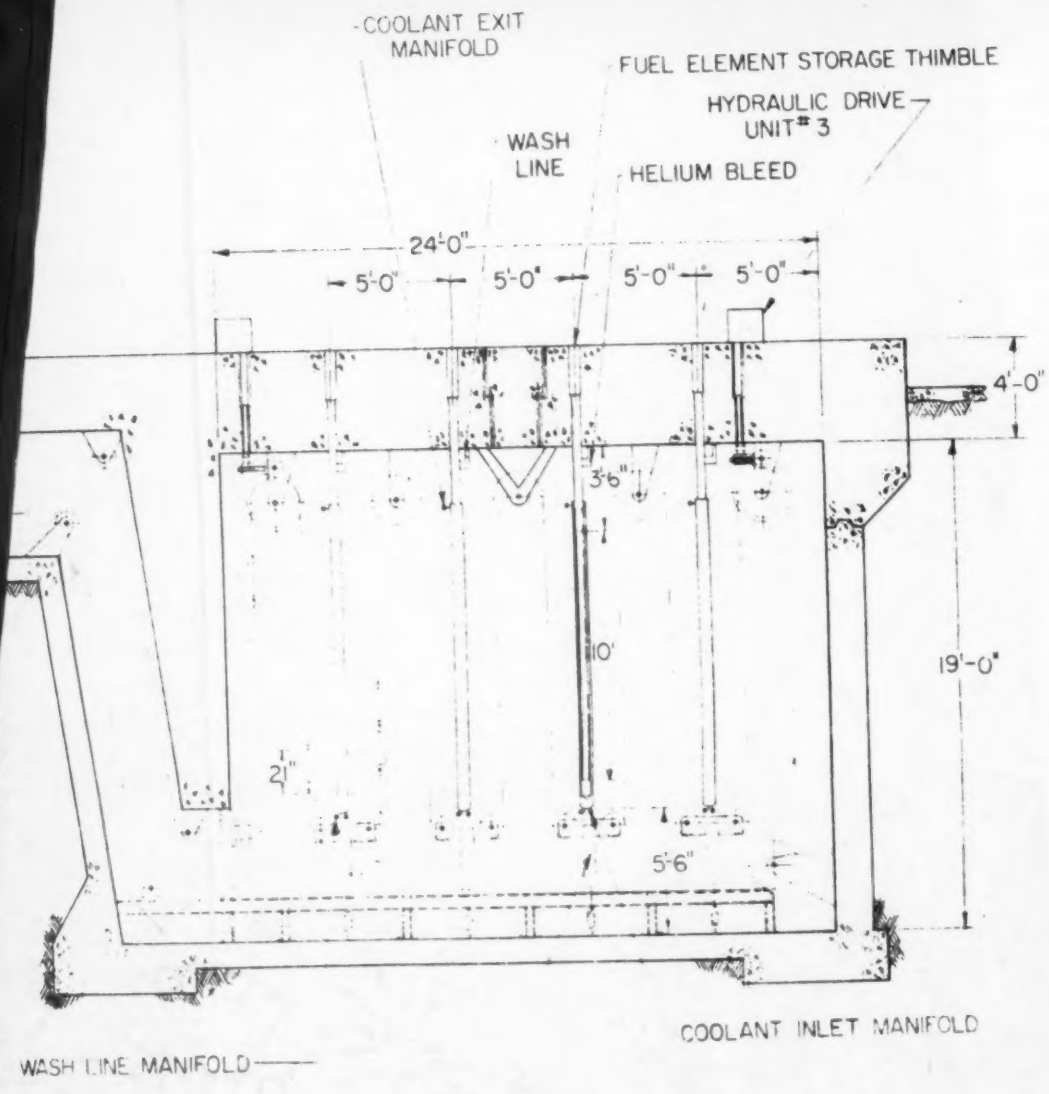


Fig. 11. Fuel Element Radiation Cell

52249 O-60-pt. 1 (Face p. 509)

D. DESIGN OF THE RADIATION FACILITY FOR USE OF FUEL ELEMENTS

1. Radiation Cell Design and Fuel Element Handling Procedures - For use in the irradiation cell, the fuel cluster is transferred to thimbles in the radiation cell shown in Fig. 11. Details of the thimble are shown in Fig. 12. As indicated in Fig. 11, the cluster is suspended from a shield plug in the top of the radiation cell. It hangs inside a double-wall stainless-steel thimble with cooling water in the annulus. There are four rows of clusters, each containing 14 clusters. Under the assumed reactor operating conditions, discussed in Section III, D, 3, 14 clusters are available from the reactor every four weeks. The fuel element hold-up period in the radiation cell is therefore 16 weeks.

The row of fuel elements constitutes a radiation plaque 10 feet high by 14-1/2 feet wide. The clusters are spaced nonuniformly to obtain a nearly uniform radiation field across the 14-1/2-foot dimension. Access to the radiation cell is by means of a plug in the top shield. The fuel elements must be removed from the thimbles to permit entry into the radiation cell.

2. Cooling and Containment of Radioactivity - The maximum cooling load for a cluster is 2.9 kw when 1 day old. The heat is produced by self-absorption of the betas and about 80 per cent of the gamma energy. The heat is transferred to the inner wall of the thimble by radiation, and is carried away by cooling water in the annulus between the two thimble walls.

If maintenance is required on the equipment in the radiation cell, the fuel elements would be transferred to the fuel storage cells provided near the reactor. Removal of the elements would permit access to the radiation cell. In the event of a leak in the cladding on the fuel rods, some activity would remain in the thimble. Washing lines are provided on each thimble to remove deposited activity. Since some fission products are difficult to remove from stainless steel, several washes might be necessary; in extreme cases of contamination, local shielding of the contaminated thimble might be required during maintenance of the equipment in the processing cell.

3. Food-Handling Conveyor - The food conveyor for the fuel element processing facility is shown in Fig. 11. There are three independent conveyor belts, each driven by three hydraulic drive units. The V3 boxes are contained in a basket which is suspended from the conveyor belt. The conveyor enters the radiation cell through a labyrinth and makes two passes between radiation plaques.

52249 O—60—pt. 1——33

52249 O-60-pt. 1 (Face p. 509)

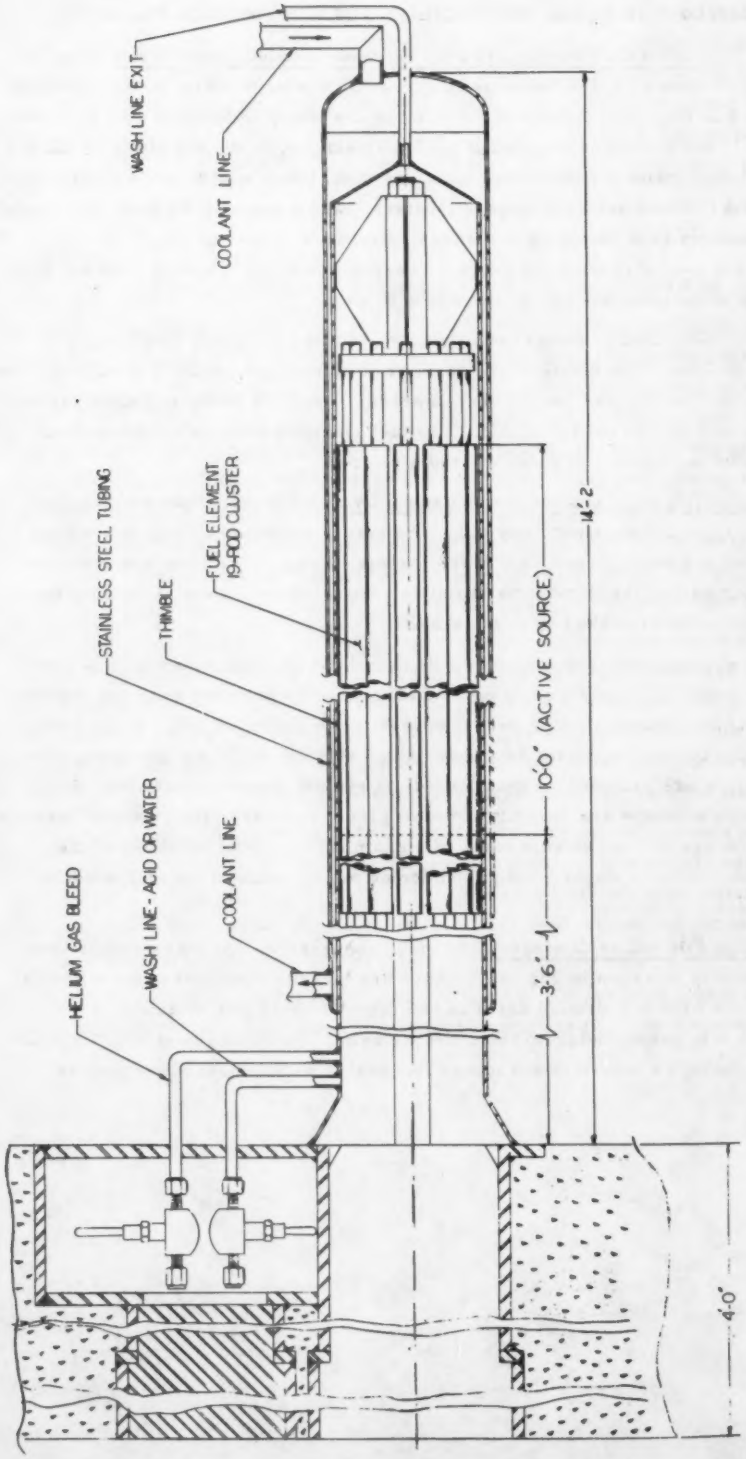


Fig. 12. Detail of Thimble Containing Fuel Cluster

There are two V3 boxes per conveyor basket. The area per basket is 52 inches by 21 inches. The two V3 boxes are 41 inches by 15-1/2 inches, so that coverage of the radiation plaque by the V3 boxes, in the conveyor region, is about 58 per cent; since the three conveyor belts cover only 150 inches of the plaque width of 174 inches, the over-all fraction of plaque coverage by V3 boxes is 50 per cent.

With the independent conveyors, three different materials can be processed simultaneously to different exposures.

E. FUEL ELEMENT GAMMA POWER AND PROCESSING CAPACITY

To obtain the gamma power of the fuel elements while in the radiation cell, it was assumed the fuel could be exposed in the reactor to 3 megawatt-days per kilogram of uranium (approximately 2700 megawatt-days per ton). With a plant factor of 70 per cent, equivalent to operating the reactor at full power 70 per cent of the time, the average specific power of the fuel during exposure is seven watts per gram. The gamma power, as a function of time from removal from the reactor, is shown in Fig. 13. The time required to reach 3 megawatt-days per kilogram at an average specific power of 7 watts/gram is 430 days. The curve of Fig. 13 was obtained by plotting the data of Fig. 6 through 9 *versus* exposure time and extrapolating to 430 days.

The fuel holdup period in the processing facility is 16 weeks, assumed to start one day after reactor shutdown and running through the 113th day. The quantity of fuel contained in the facility is 6440 kg. The peak gamma power, obtained with one row of clusters 1 day old, the second row 29 days old, the third row 57 days old, and the fourth row 85 days old, is 38.7 kw. The minimum gamma power, just before fresh elements are added, is 19.3 kw.

The average gamma power is 25.9 kw of which 19 per cent, or 4.9 kw, escapes the cluster and containing themble. Detailed calculations of the gamma-ray utilization have not been possible in this study, but an estimate of 25 per cent for each of the gamma sources has been obtained. On the basis of this estimate, about 1.2 kw of gamma power can be absorbed in the food being processed.

For a food item requiring 2.5×10^6 reps, the capacity of the facility is 5 tons per 24-hour day. At the other exposure extreme, 840 tons of potatoes could

Fig. 12. Detail of Thimble Containing Fuel Cluster

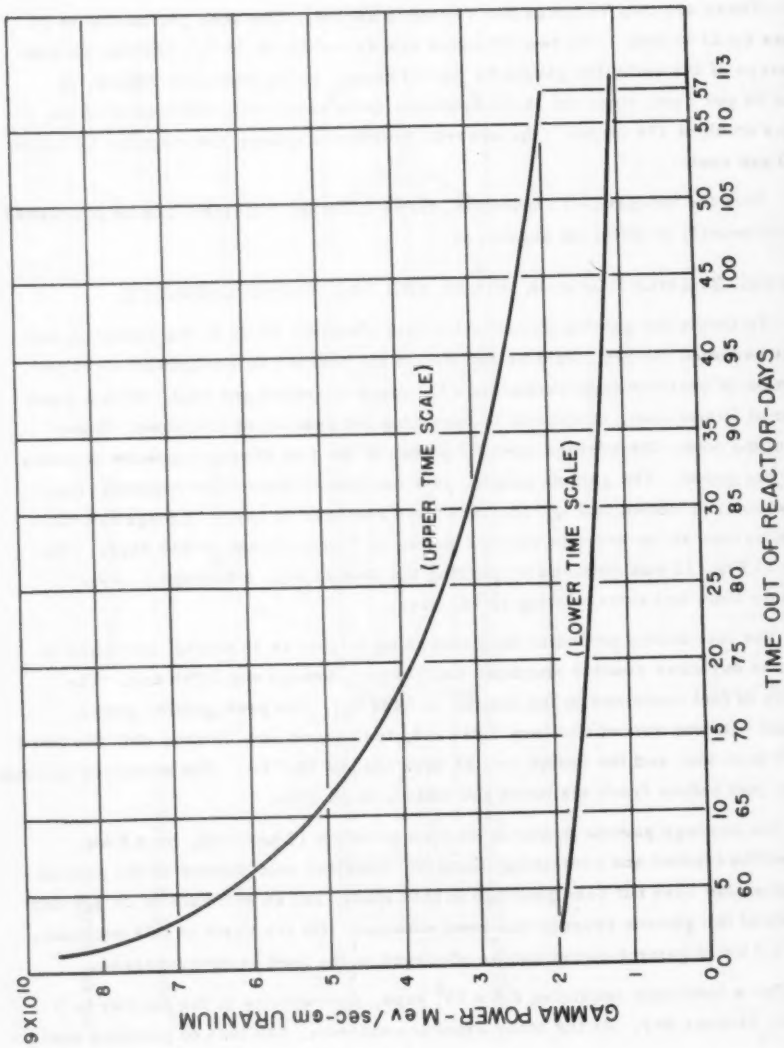


Fig. 13. Gamma Power of Fuel After Removal From Reactor

be irradiated to 1.5×10^4 reps in 24 hours. The time required for a package to absorb 2.5×10^6 reps is over four days; potatoes would require 38 minutes.

F. COST ESTIMATES FOR THE FUEL ELEMENT FACILITY

For the purposes of this study, the estimates of capital and operating costs are limited according to the discussion of Section I, page 8. Capital cost estimates were obtained only for the radiation cell with its associated equipment including the food-handling conveyors. Operating cost estimates were limited to special costs associated with a particular radiation source.

The estimated cost of the radiation cell is $229,000. This figure includes the cost of shielding, establishment and provisions for maintenance of the radiation field in the cell, and the refrigeration equipment required to maintain a cell temperature of 12° F.

The estimated cost of the three-belt conveyor system including the drive units is $222,000. The total capital investment estimate is therefore $451,000. As discussed in Section I, the number of significant figures in these estimates do not reflect the accuracy with which they are known.

The only special operating cost which might be assessed against this radiation facility is a rental charge on the fuel elements. This charge is neglected; its inclusion would not affect the conclusions of this report.

With the above investment figures, the following partial unit processing costs are obtained:

	Exposure		
	2.5×10^6 reps	10^5 reps	1.5×10^4 reps
Annual Through-put (at 90% Plant Factor)	3.31×10^6 lbs/yr	8.25×10^7 lbs/yr	5.51×10^8 lbs/yr
Capital Costs (at 15% per year)	2.05¢/lb	0.0820¢/lb	0.0123¢/lb

These costs are compared with those of the other radiation sources in Section X.

Fig. 13. Gamma Power of Fuel After Removal From Reactor

IV. RADIATION FACILITY USING GASEOUS FISSION PRODUCTS

In a reactor using a fluid fuel, the possibility exists of using the fission products evolved from the fuel as a source of gamma rays for radiation processing.

A. SOURCES OF GASEOUS FISSION PRODUCTS

The chemical elements among the fission products which are gaseous and readily removable from the fuel system of a fluid-fuel reactor depend to some extent upon the nature of the fuel material. The noble-gas fission products can be removed from any of the possible fluid fuels. If the fuel is a high temperature material such as a liquid metal, many other chemical elements among the fission products will be volatile and removable from the fluid.

Two types of fluid-fuel reactors have received extensive study. One of these uses fuel consisting of a solution of a uranium salt in light or heavy water. The several "water boiler" or solution-type research reactors which have been built and operated utilize this fluid fuel. The second type of fluid-fuel reactor will use a fuel consisting of a solution or slurry of uranium in liquid bismuth. Those chemical elements which would be gaseous in these two reactor fuels would depend upon the temperature of the fuels and must be expected to be quite different for the two fuels.

The gamma energy spectrum and the gamma power available in the gaseous fission products per unit of reactor power must therefore be expected to differ for these two fluid fuels.

In the liquid-metal fuel system an inert atmosphere, perhaps of helium, would be used over the liquid fuel. The helium would dilute the fission product gases considerably and cannot readily be separated from them. After a long period of reactor operation it might be possible to establish a reactor atmosphere consisting essentially of fission gases, and an intense gamma source could be obtained.

In the aqueous-fuel system, the fuel atmosphere consists of water vapor, deuterium (with heavy water) and oxygen with traces of fission product gases. The deuterium and oxygen are produced by radiolytic decomposition of the water and must be recombined in the system. A slight excess of oxygen is maintained to reduce corrosion rates. Recombination of the deuterium and oxygen and

condensation of the resulting heavy-water vapor reduces the volume of gases to a great extent; the excess of oxygen complicates the problem of establishing an intense gamma source since it cannot readily be removed from the system.

Because of limitations on the scope of this study of radiation sources, a choice had to be made between these two sources of gaseous fission products. Since the aqueous-fuel reactors have been built and operated and because there is a limited amount of data available on the gaseous fission products from this fuel system, the aqueous-fuel reactor was selected for study. While the results of this study indicate that the aqueous fuel is a promising source of gammas for radiation processing, it is possible that the liquid-metal fuel, with its wider spectrum of volatile fission products, will prove more advantageous.

B. CHARACTERISTICS OF GASEOUS FISSION PRODUCTS FROM AN AQUEOUS-HOMOGENEOUS REACTOR

The best data available on fission product gas activities are reported in LA-1521.[7] In this report a study is made of the exposures from a liter of the gases evolved from the core of SUPO, an aqueous-homogeneous reactor. The fuel is a solution of uranyl nitrate in H_2O and is operated at about 75° C.

The observed activity is shown in Fig. 14, reproduced from LA-1521. The activity, according to this report, is due mostly to Xe and Kr isotopes. Attempts to compute the activity from known fission product data resulted in values much lower than the observed activity; this is apparently due to lack of data on the short-lived noble gas activities and possibly to neglect of some materials, such as bromine and iodine, which could be volatile in the system.

An attempt was made to obtain the energy characteristics of the emitted radiation by making an empirical fit to the data of Fig. 14. In this effort three energy groups were assumed for the gammas, and the activity of each group obtained by requiring agreement with the absorption characteristics indicated by the curves of Fig. 14. Positive values for all three activities were obtained only when one of the group energies was assumed to be less than 0.5 Mev. The three energies selected in this manner are 0.3, 1.5 and 3.0 Mev. The corresponding relative activities are 10.9×10^{13}, 0.23×10^{13} and 0.40×10^{13} photons/sec respectively. This analysis indicates that the gamma-ray energy spectrum is rather poor for processing since the large fraction of low-energy gammas would produce large exposure variations in the food items.

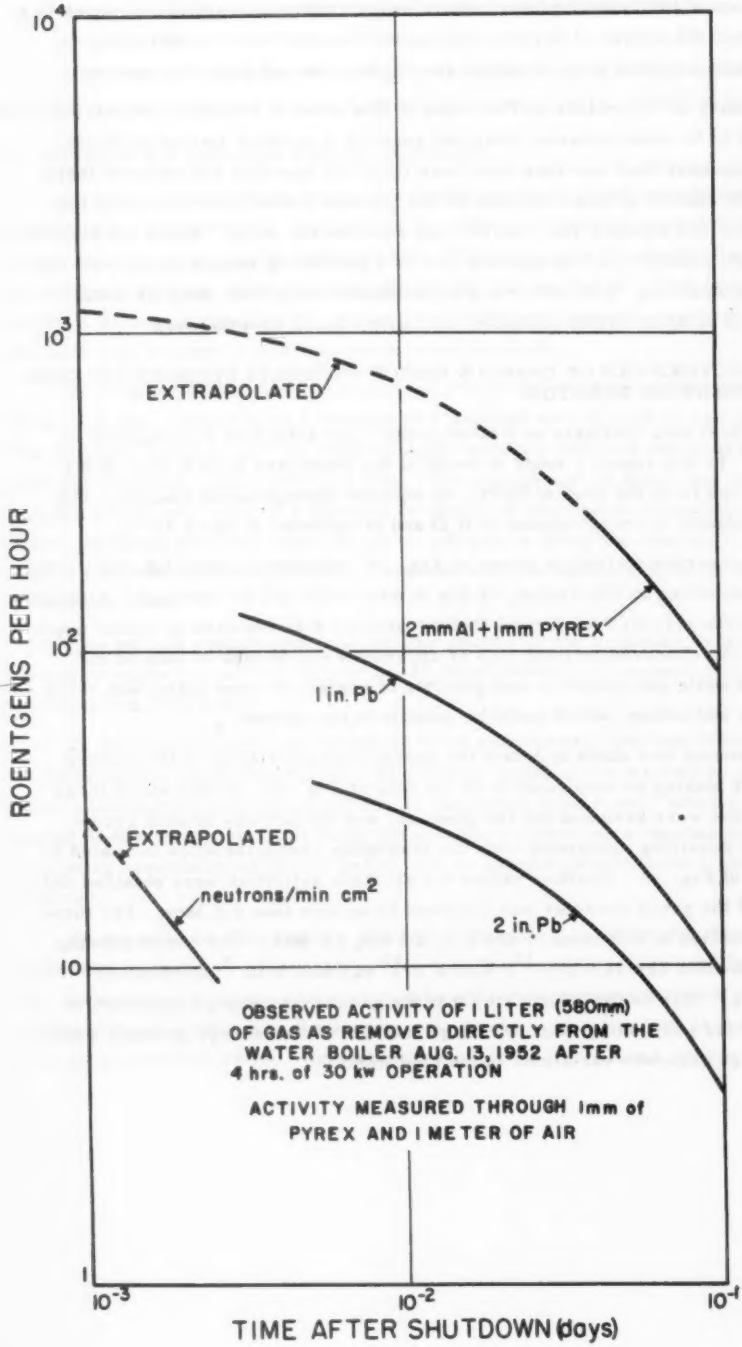

ROENTGENS PER HOUR
TIME AFTER SHUTDOWN (days)
EXTRAPOLATED
2 mm Al + 1mm PYREX
1 in. Pb
EXTRAPOLATED
neutrons/min cm²
2 in. Pb
OBSERVED ACTIVITY OF 1 LITER (580mm) OF GAS AS REMOVED DIRECTLY FROM THE WATER BOILER AUG. 13, 1952 AFTER 4 hrs. of 30 kw OPERATION
ACTIVITY MEASURED THROUGH 1mm of PYREX AND 1 METER OF AIR

Fig. 14. Decay of Radioactive Water Boiler Gas

Analysis of the total gamma energy available from the gases resulted in the conclusion that 6.6 watts were available per kilowatt of reactor power. This would make a small power reactor, e.g. 50 megawatts thermal power, an extremely copious source of gammas for processing. However, the measurements reported above were made on a closed gas system; a reactor of several megawatts requires an open system with provisions for disposal, and the gamma power available per unit of reactor power is reduced. This is discussed in Section IV-D on gamma power and processing capacity of the fission product gases facility.

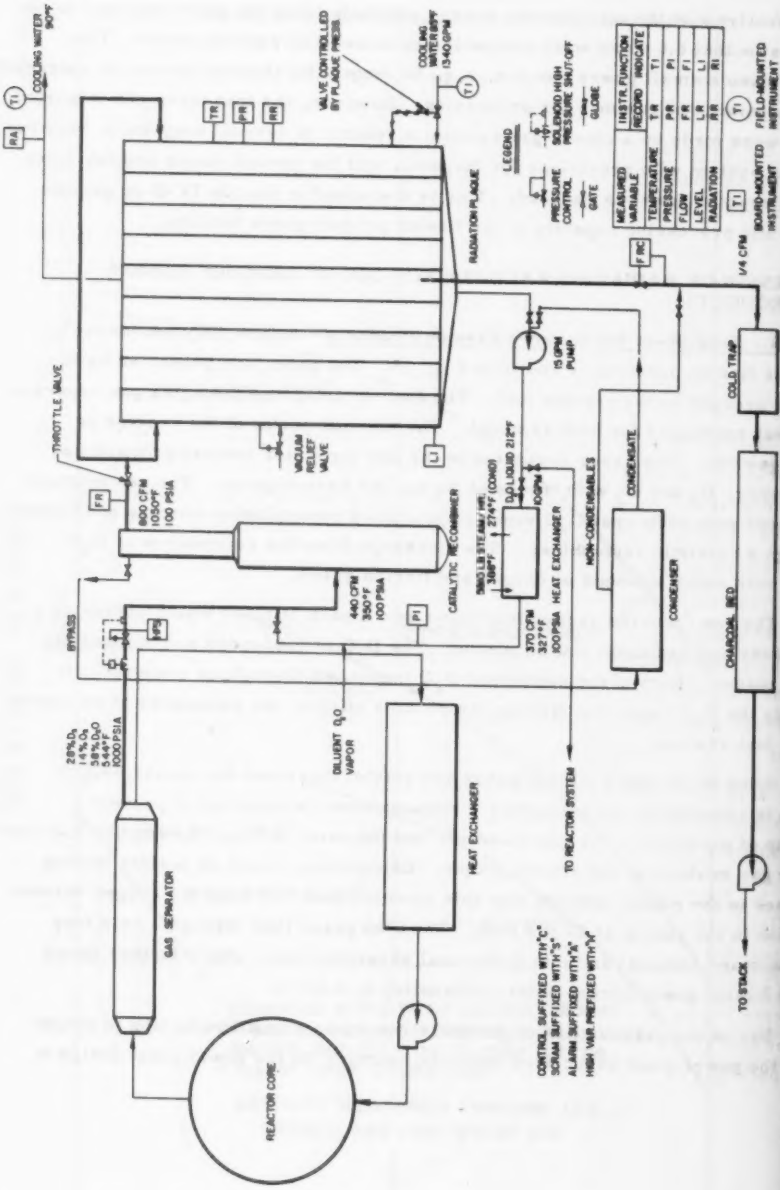
C. DESIGN OF RADIATION FACILITY FOR USE OF GASEOUS FISSION PRODUCTS

1. Flow Sheet for Gaseous Fission Products - A flow diagram for the gaseous fission products is shown in Fig. 15. The gases are generated by the fission process in the reactor fuel. The fuel is circulated through a gas separator to a heat exchanger for heat removal. The thermal power of the reactor is 50 megawatts. The gases separated in the gas separator consist primarily of D_2O vapor, D_2 and O_2 with traces of Xe and Kr fission gases. The gas mixture is diluted with additional D_2O vapor to produce a nonexplosive mixture and flows through a catalytic recombiner. The discharge from the recombiner is D_2O vapor with small amounts of oxygen and fission gases.

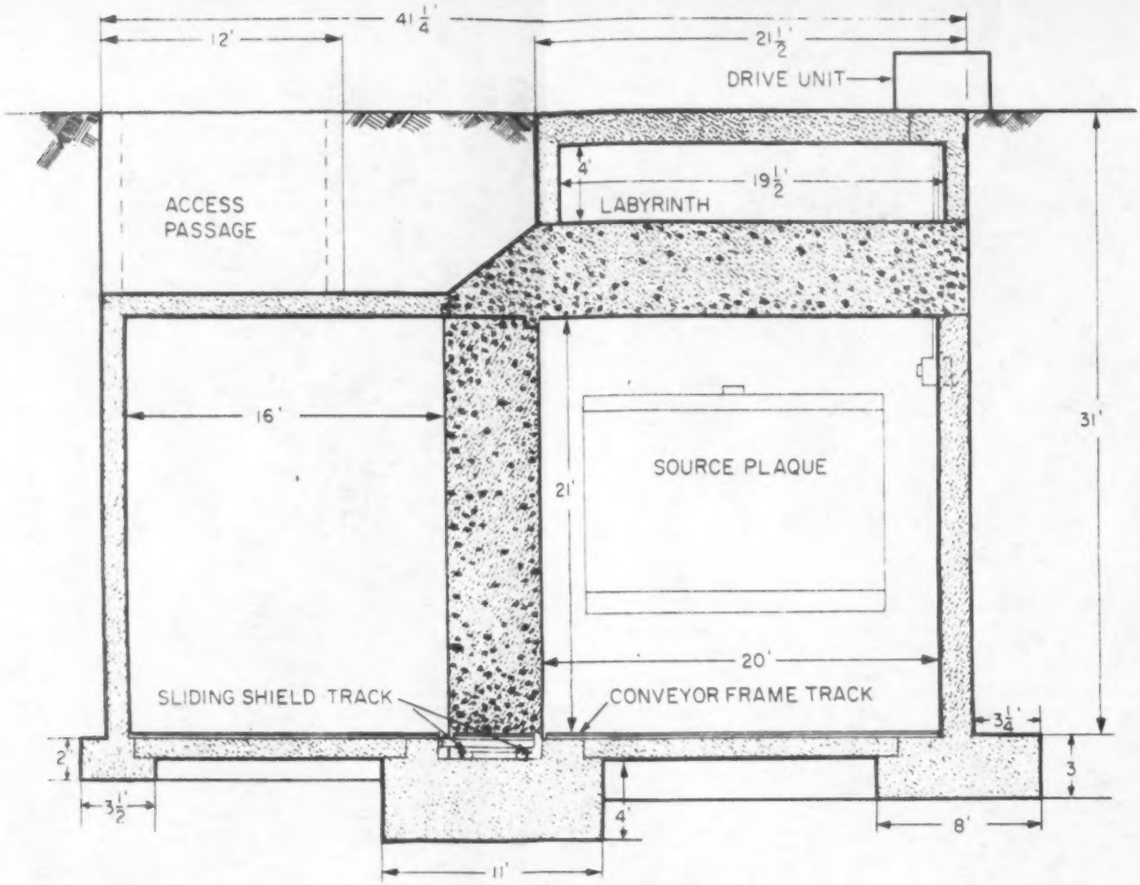
The gas from the recombiner flows into a bank of tubes which serves as a condenser and radiation source plaque. The D_2O is condensed and pumped out of the plaque. Part of the condensed D_2O is pumped through an evaporator to provide the D_2O vapor for diluting the reactor off-gas; the remainder is returned to the fuel system.

Some of the noble fission gases are stable; these and the excess oxygen which is admitted to the condenser - radiator must be removed to prevent a buildup of pressure. The gas bleed-off line indicated in Fig. 15 removes 0.26 cfm of the gas mixture in the source plaque. Calculations based on perfect mixing of gases in the plaque indicate that this removal rate will keep the oxygen volume fraction in the plaque at 10 per cent. The bled gases flow through a cold trap for moisture removal and into a charcoal absorption bed, where further decay of the fission gases occurs before exhausting to a stack.

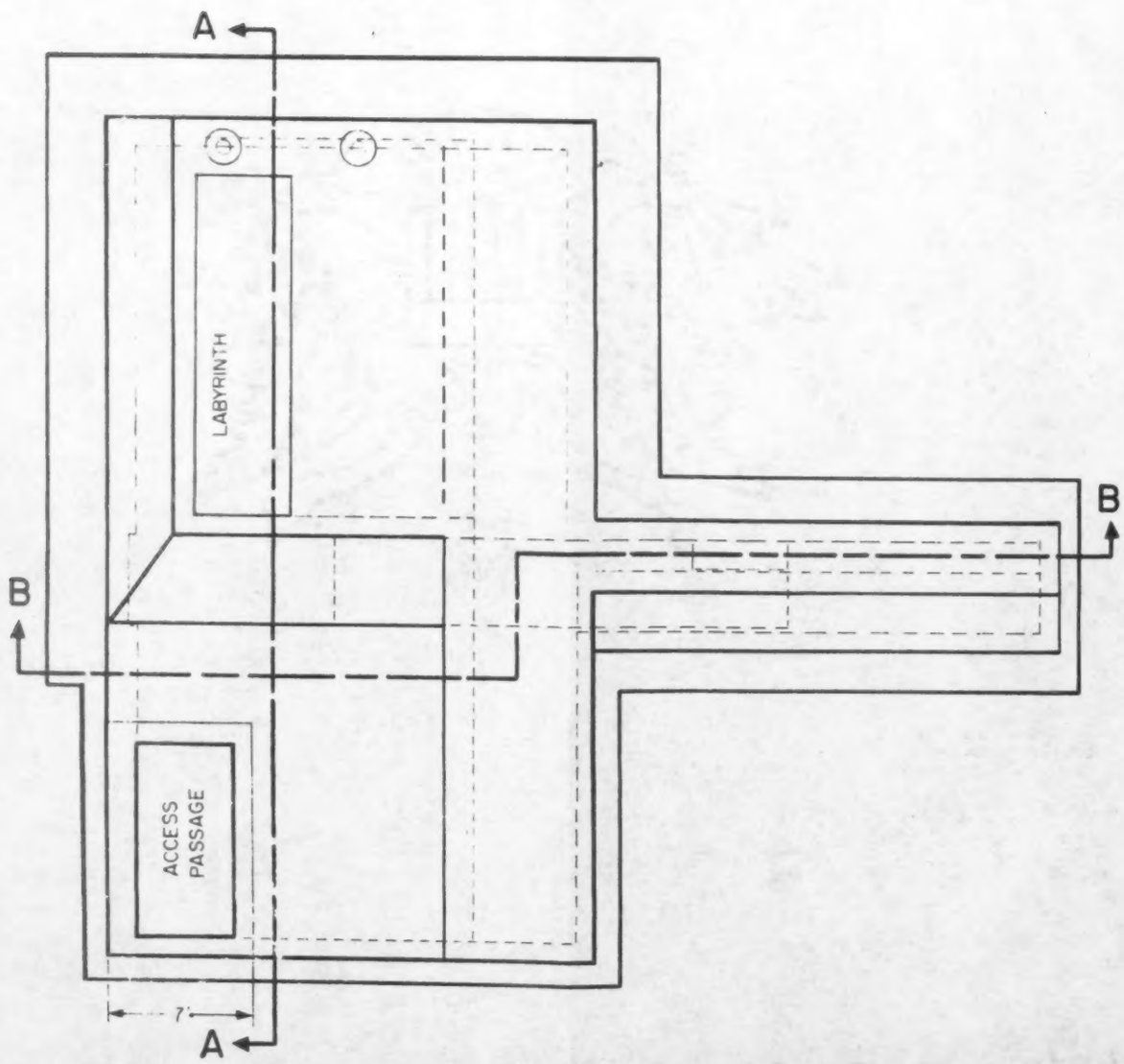
Use of the gaseous fission products results in a small reduction in output from the power plant associated with this reactor. In the power plant design it


COOLING WATER 90°F
COOLING WATER 89°F 1340 GPM
VALVE CONTROLLED BY PLADUE PRESS
RADIATION PLADUE
LEGEND
SOLENOID HIGH PRESSURE SHUT-OFF
PRESSURE CONTROL
GATE
GLOBE
MEASURED VARIABLE
INSTR. FUNCTION RECORD INDICATE
TEMPERATURE TR TI
PRESSURE PR PI
FLOW FR FI
LEVEL LR LI
RADIATION RR RI
BOARD-MOUNTED INSTRUMENT
FIELD-MOUNTED INSTRUMENT
THROTTLE VALVE
VACUUM RELIEF VALVE
800 CFM 1050°F 100 PSIA
CATALYTIC RECOMBINER
360 LB STEAM/HR 388°F
90 LIQUID 212°F
10 GPM
HEAT EXCHANGER
274°F (COND)
15 GPM PUMP
NON-CONDENSABLES
CONDENSATE
CONDENSER
COLD TRAP
1/4 CFM
440 CFM 350°F 100 PSIA
370 CFM 327°F 900 PSIA
BYPASS
CHARCOAL BED
28% O2 14% CO2 58% H2O 544°F 1000 PSIA
DILUENT CO2 VAPOR
HEAT EXCHANGER
TO REACTOR SYSTEM
GAS SEPARATOR
REACTOR CORE
CONTROL SUFFIXED WITH "C"
SCRAM SUFFIXED WITH "S"
ALARM SUFFIXED WITH "A"
HIGH VAR. PREFIXED WITH "H"
TO STACK

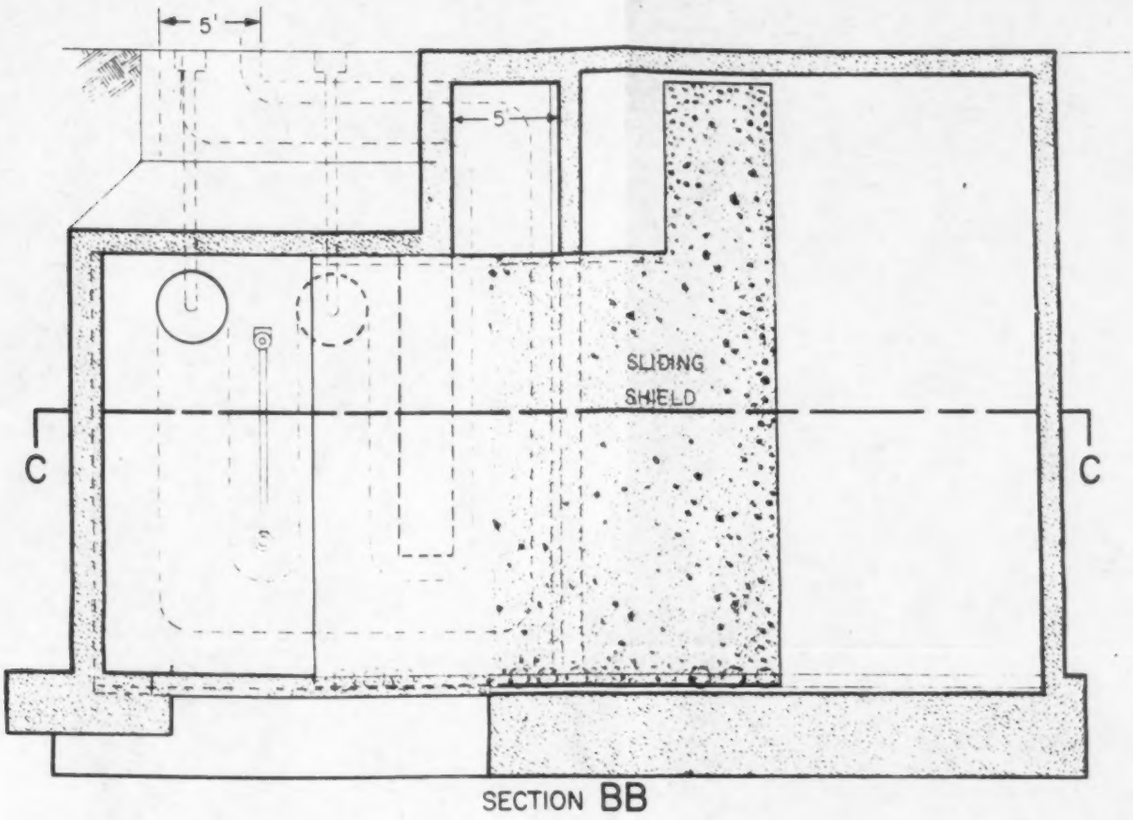
BOARD-MOUNTED INSTRUMENT
FIELD-MOUNTED INSTRUMENT


41 1/4'
12'
21 1/2'
DRIVE UNIT
4'
19 1/2'
LABYRINTH
ACCESS PASSAGE
16'
21'
SOURCE PLAQUE
31'
20'
SLIDING SHIELD TRACK
CONVEYOR FRAME TRACK
3 1/4'
2'
3'
3 1/2'
4'
8'
11'

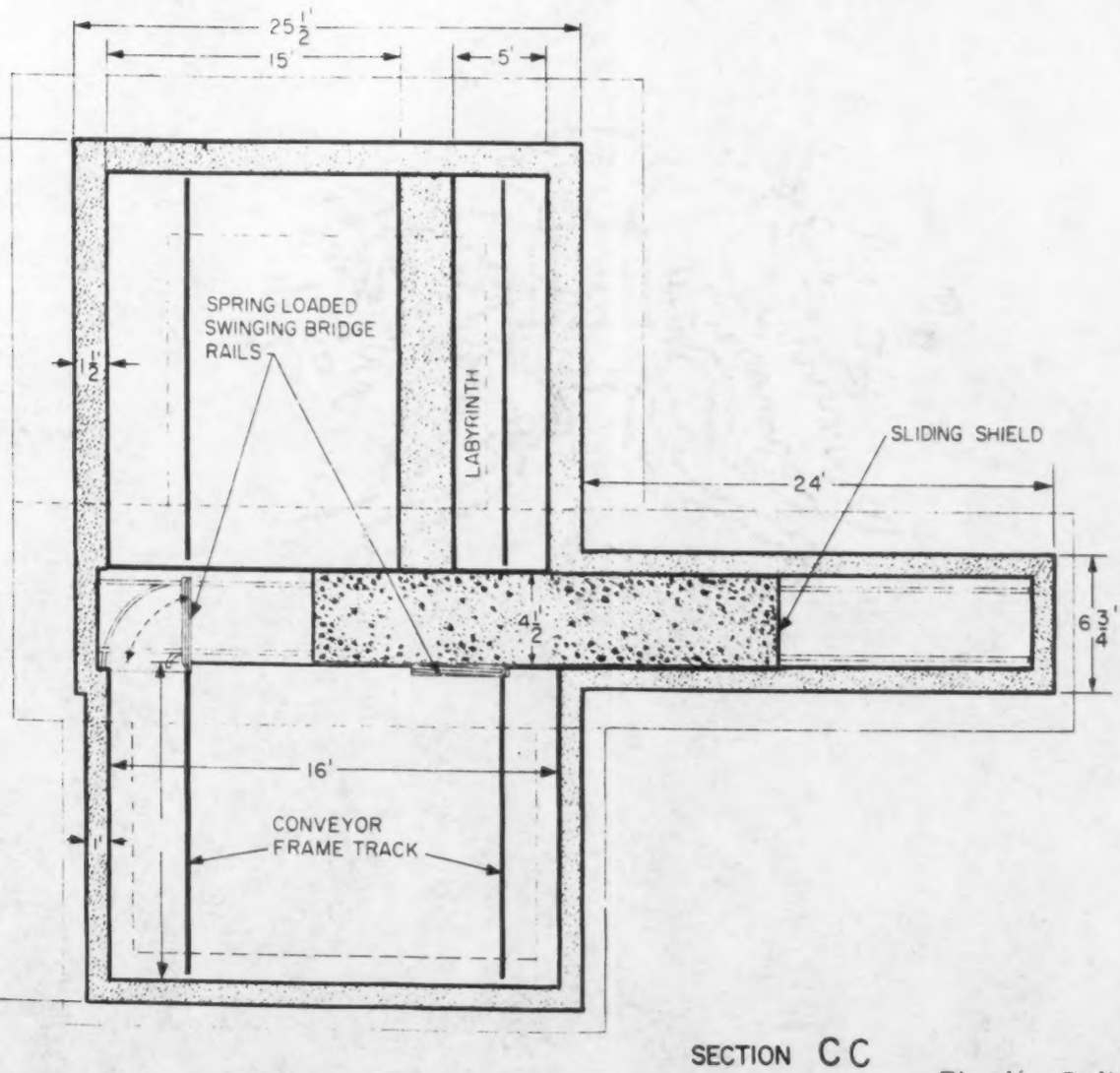
SECTION A A


A
B
LABYRINTH
ACCESS PASSAGE
7'

43'



SECTION BB



SECTION CC

Fig. 16. Radiation Cell for Use of Gaseous Fission Products

52249 O-60-pt. 1 (Face p. 519)

52249 O - 60 - pt. 1 (Face p. 519)

is expected that the heat generated in the gas recombiner will be used for the generation of steam. Use of the gaseous fission products for irradiation purposes in the manner indicated above results in the loss of this heat energy. The effect on the power plant is a reduction in output of about 6 per cent.

2. Radiation Cell Design - The radiation cell for use of gaseous fission products is shown in Fig. 16. There is a single radiation plaque 11 feet high by 14 feet wide. Details of the plaque appear in Fig. 17.

It is expected that the radiation plaque will be difficult to decontaminate when conveyor maintenance is required. Provision is therefore made for removing the conveyor system from the radiation cell for maintenance. A sliding shield plug is provided for this purpose as indicated in Fig. 16.

3. Cooling and Containment - Condensing of the D_2O vapor in the radiation plaque requires a relatively large cooling system. The gas flow from the recombiner is 800 cfm at 1050° F and 100 psia; this is throttled into the radiation plaque to a pressure slightly above that of the cooling water. The tubes which make up the condenser - radiator are enclosed in larger tubes with cooling water in the annulus. The cooling water flow is 1340 gallons per minute; the cooling water rejects heat in a cooling tower.

The cooling water is monitored for leaks in the radiation plaque. In the event of trouble with the plaque, the gases from the recombiner are routed to a standby condenser; the D_2O is condensed and returned to the reactor fuel system, and the noncondensable gases flow to the charcoal absorption bed. The standby condenser would permit power-plant operation despite a failure in the radiation plaque.

Repairs to the plaque would be difficult; if sufficient decontamination with solvents proved impossible, repairs might be made under water after flooding the radiation cell.

4. Food Handling Conveyor - The conveyor system consists of three parallel belts, each of sufficient width to handle two of the V3 boxes. The spacing between baskets is 52 inches by 21 inches. The two V3 boxes are 41 inches by 15-1/2 inches, so that coverage of the radiation plaque by the packages in the conveyor region is about 58 per cent; since the three conveyor belts cover only 89 per cent of the width of the plaque, the overall fraction of plaque coverage by food packages is 52 per cent.

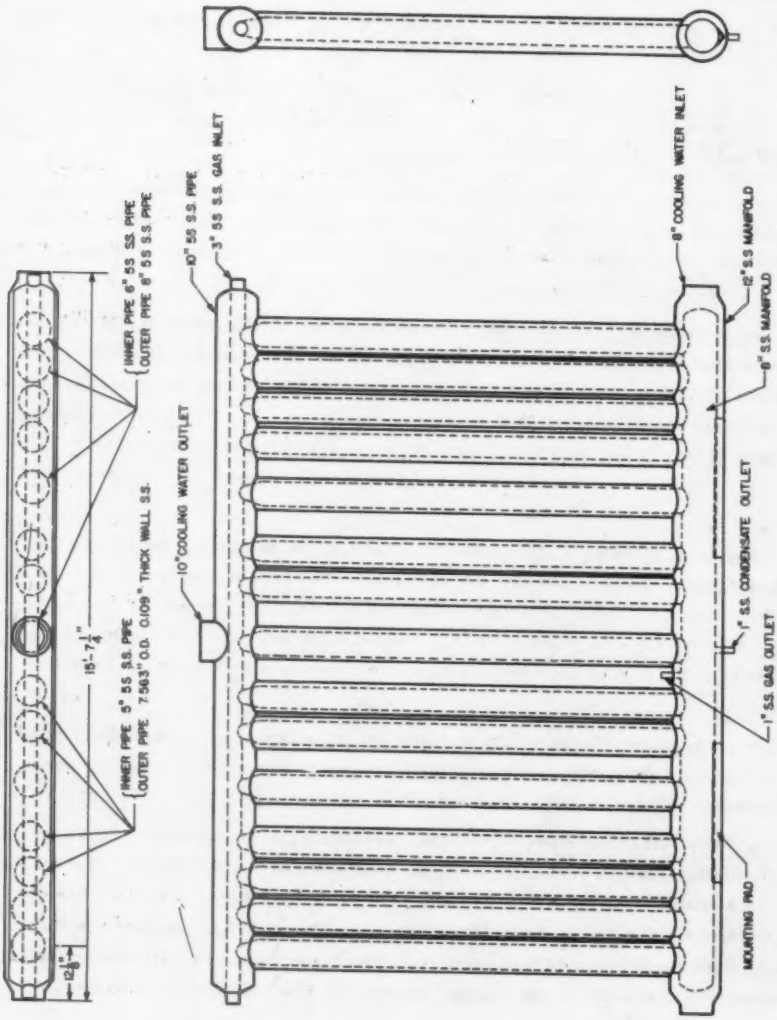

INNER PIPE 6" SS SS. PIPE
OUTER PIPE 8" SS S.S. PIPE
INNER PIPE 5" SS SS. PIPE
OUTER PIPE 7.563" O.D. 0.109" THICK WALL S.S.
15'-7¼"
12½"
10" SS S.S. PIPE
3" SS S.S. GAS INLET
10" COOLING WATER OUTLET
8" COOLING WATER INLET
2" S.S. MANIFOLD
8" S.S. MANIFOLD
1" SS. CONDENSATE OUTLET
1" SS. GAS OUTLET
MOUNTING PAD

Fig. 17. Radiation Plaque for Gaseous Fission Products

As with the fuel element facility, the three conveyor belts are independently driven so that three different materials could be processed simultaneously.

D. GAMMA POWER AND PROCESSING CAPACITY

The gamma power of the radiation source described in the preceding paragraphs is highly uncertain and will probably not be determined without an experimental program. As discussed in Section IV-B, the experimental data of LA-1521[7] indicate that 6.6 watts of gamma power are available from the SUPO reactor per kilowatt of reactor power. The measurements were made on a closed gas system after the small homogeneous reactor had been operated for about four hours.

Calculations of the gaseous fission product activity, using the known characteristics of the noble-gas fission product chains, result in a much lower figure for the gamma power per unit of reactor power. Neglecting the long-lived fission products, i.e. those with half life of the order of a month or longer, the calculated activity in a closed gas system is about 1.5 watts per kilowatt of reactor power.

The fission gas system presented in this section is not closed. There is a large flow of D_2O through the source plaque which would tend to remove some of the activity, particularly the rubidium and cesium daughters of the krypton and xenon gases. In addition there is a flow of gases from the plaque to prevent the buildup of oxygen and stable noble gases.

The activity in the source plaque was calculated assuming a 50 megawatt reactor. These calculations were based upon the following assumptions:

1. The transit time from reactor to radiation plaque is negligible.
2. All daughter products remain suspended in the gas rather than deposit on the walls. They are therefore removed from the plaque in the gas stream.
3. The yields (atoms per fission) of the daughter products are equal to the yields of the noble-gas precursors.
4. The gas bleed rate is 0.26 cubic feet per minute. The gas bleed rate is determined by the amount of oxygen which can be tolerated in the radiation plaque; its presence reduces the efficiency with which the D_2O is condensed on the surfaces of the tube walls. To keep the oxygen content of the gas in the plaque at 10 per cent, a removal rate of

Fig. 17. Radiation Plaque for Gaseous Fission Products

0.26 cfm is required. The plaque volume is 40 cubic feet, so the average holdup time for the fission gases is about 2-1/2 hours. Several of the radioactive isotopes have half lives longer than this and are removed from the tank with little contribution to the gamma power.

Calculation of the gamma activity with the above assumptions results in a predicted gamma power of 28.1 kilowatts for the 50-megawatt reactor, or 0.56 watts per kilowatt of reactor power. If the assumption is made that all daughter products deposit on the walls and are not washed out with the D_2O condensate, a gamma power of 58.9 kilowatts is obtained. The calculated power with no removal is 73.5 kilowatts or 1.47 watts per kilowatt of reactor power. This is less than one fourth of the measured activity in a closed gas system.

In view of the uncertainty in the calculated gamma power of the open gas system, and since the reported experimental data indicate that the activity in the closed gas system is considerably greater than the calculated value, the gamma power of the gaseous fission product source discussed in this section is arbitrarily taken to be 50 kilowatts. An experimental program is required to obtain a more accurate figure.

Of the 50 kilowatts, about 25 per cent can be usefully absorbed in food products. The capacity of the radiation cell is then 51.5 tons per 24-hour day of food irradiated to 2.5×10^6 reps. With a maximum conveyor speed of 30 feet per minute the minimum exposure is about 3.5×10^4 reps in material packed to 50 # per V3 box. The time required for a food package to absorb 2.5×10^6 reps is about eight hours; 3.5×10^4 reps could be absorbed in 7 minutes.

E. COST ESTIMATES FOR THE GASEOUS FISSION PRODUCTS FACILITY

The estimates of capital and operating costs are limited, for the purposes of this study, according to the discussion of Section I, page 8.

The estimated cost of the radiation cell is $445,000. This figure includes the cost of shielding, establishment and provisions for maintenance of the radiation field in the cell, and the refrigeration equipment required to maintain a cell temperature of 12° F.

The estimated cost of the food-handling conveyor system is $208,000. The total investment is therefore $653,000.

The only special operating cost associated with this radiation source is the cost arising from the fact that use of the gaseous fission products for food irradiation reduces the reactor power plant capacity by 6 per cent, as indicated in Section IV-C, 1. The electrical capacity of the power associated with the 50 Mw reactor is about 12,500 kw. The loss in electrical capacity, which must be charged to the cost of radiation processing, is therefore 750 kw.

The value of the power is the marginal cost of power from the plant. This marginal cost of power depends primarily on fuel and operating costs for the plant; since these are presently unknown, a figure of 4 mills per kilowatt-hour is assumed. The resulting contribution ot the cost of radiation processing is $3 per hour.

With the above figures, the following partial unit processing costs are obtained:

	Exposure		
	2.5×10^6 reps	10^5 reps	3.5×10^4 reps (min)
Annual Through-put (at 90% Plant Factor)	3.37×10^7 lbs/yr	8.42×10^8 lb/yr	2.40×10^9 lb/yr
Capital Costs (at 15% per year)	0.290¢/lb	0.0116¢/lb	0.0041¢/lb
Loss of Electrical Output	0.070¢/lb	0.0028¢/lb	0.0010¢/lb
Partial Unit Costs	0.360¢/lb	0.0144¢/lb	0.0051¢/lb

V. RADIATION FACILITY USING A SEPARATED FISSION PRODUCT

The spent fuel elements and the gaseous fission products discussed in the preceding paragraphs have the disadvantages of a wide spectrum of gamma energies and half lives. The low-energy gammas produced by these sources will be troublesome in radiation processing if narrow limits on radiation exposure are required. If a particular isotope is isolated from the mixture of materials

in gross fission products, some choice of half life and gamma characteristics is possible. This advantage is offset by the disadvantage of the high cost of separation. This cost is not yet firmly established. The price at which this source could compete with the other radiation sources of this study is estimated in Section X.

Inspection of the fission products, Table I, page 27, leads to the choice of cesium-137 as the most appropriate isotope for a gamma source. It is produced with a good yield, emits a single gamma ray with reasonable penetrating ability and has a long half life.

A. CHARACTERISTICS OF CESIUM-137

Cesium-137 is the third member of the mass 137 fission product chain. It is produced with a yield of 0.062 atoms per fission. The cesium recovered from gross fission products contains 39.7 atom per cent cesium-133, 28.5 atom per cent cesium-135, 31.8 atom per cent cesium-137 and a negligible trace of cesium-136. Cesium-133 is stable; cesium-135 has a half life of 3×10^6 years and emits no gamma. Therefore, essentially all of the gamma activity of the mixture is due to cesium-137. The chloride salt of cesium can be packed into stainless-steel tubes to a density of 2.65 gm/cm^3 with a specific activity of 25 curies per gram.

Cesium-137 emits a 0.66 Mev gamma in 92 per cent of its disintegrations. The most recently measured half life is 30 years.

B. DESIGN OF A RADIATION FACILITY USING CESIUM-137

1. Radiation Cell Design and Source Handling Procedures - The radiation cell for use of cesium-137 is shown in Fig. 18 and 19. The cesium is contained in 1-1/8 inch diameter stainless-steel tubes nine feet long. The tubes lie in a horizontal plaque 14 feet wide and are cooled by water flowing across the tube bank.

The tubes of CsCl are received in a shipping cask which is opened under water in the pool indicated in Fig. 18. The tubes are loaded manually from the cask to the source conveyor on which they are moved into the radiation cell. When maintenance is required in the cell, the source is moved back to the pool; access to the cell is by means of a ladder in the food-conveyor labyrinth or through the shield plug in the top of the cell.

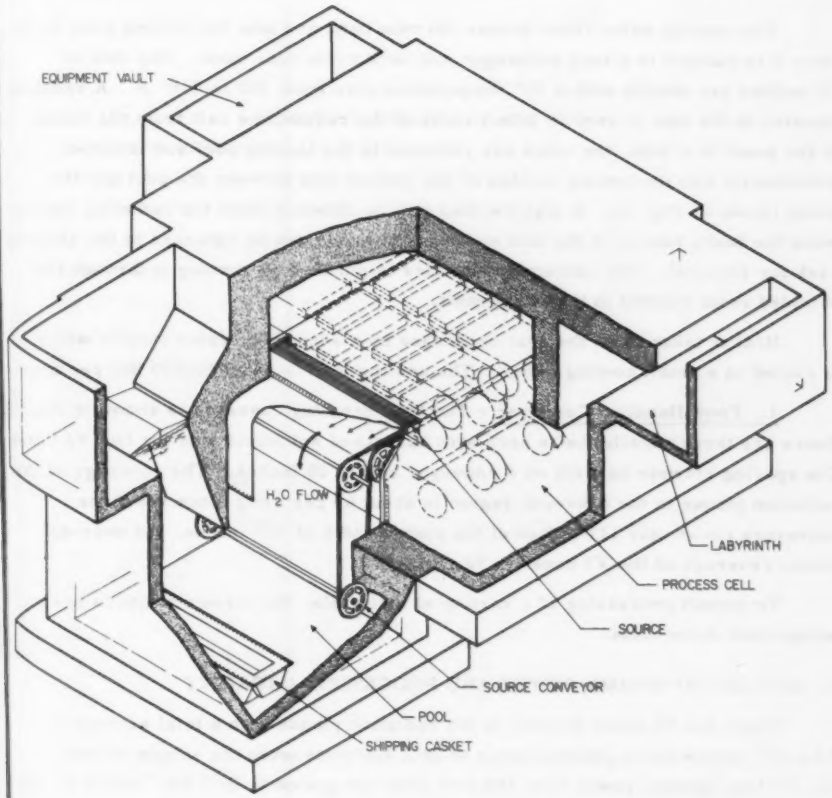


Fig. 18. Radiation Cell for Use of Cs-137 - Isometric

2. Cooling and Containment - The tubes of CsCl and the cooling water are contained in a thin tank of stainless steel. The tank provides a secondary container for the radioactive cesium.

The cooling water flows across the tube bank and into the loading pool; from here it is pumped to a heat exchanger and back to the tube bank. The flow is 10 gallons per minute with a 10° temperature rise from 100 to 110° F. A radiation monitor in the line is used to detect leaks of the radioactive salt from the tubes. In the event of a leak, the tubes are returned to the loading pool and inserted individually into the testing section of the coolant line between the pool and the pump shown in Fig. 18. A high reading will be obtained from the radiation monitor when the faulty tube is in the test section. The tube can be returned to the shipping cask for removal. The contaminated water is purified by running it through the shielded resin column in the pump vault.

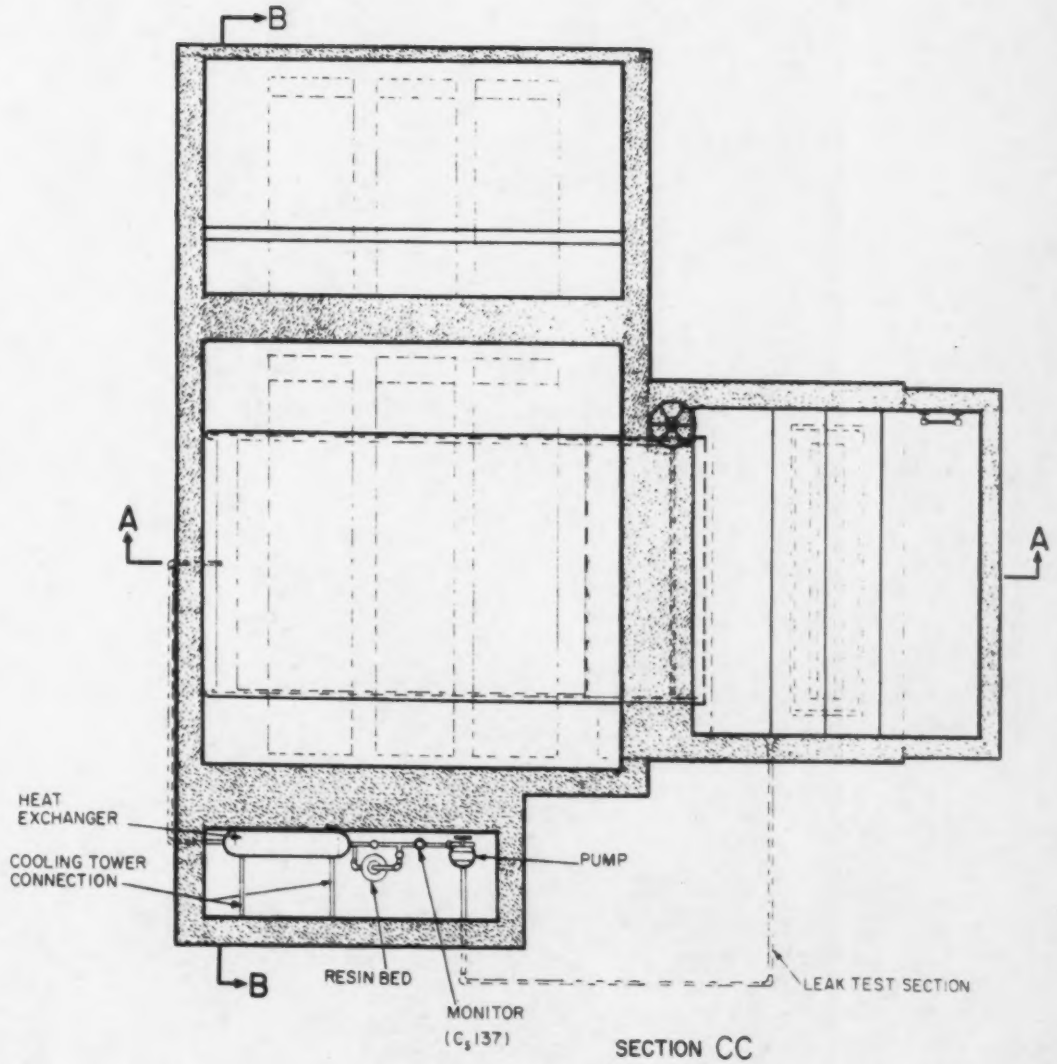
Heat is taken from the heat exchanger by a secondary water stream which is cooled in a small cooling tower. The cooling load is about 50,000 Btu per hour.

3. Food-Handling Conveyor - The food-handling conveyor is shown in Fig. 19. There are three parallel belts each with baskets of sufficient size for two V3 boxes. The spacing between baskets on a conveyor belt is 20 inches. The coverage of the radiation plaque in the conveyor region is about 63 per cent; since the three conveyors cover only 141 inches of the plaque width of 170 inches, the over-all plaque coverage of the V3 boxes is 52 per cent.

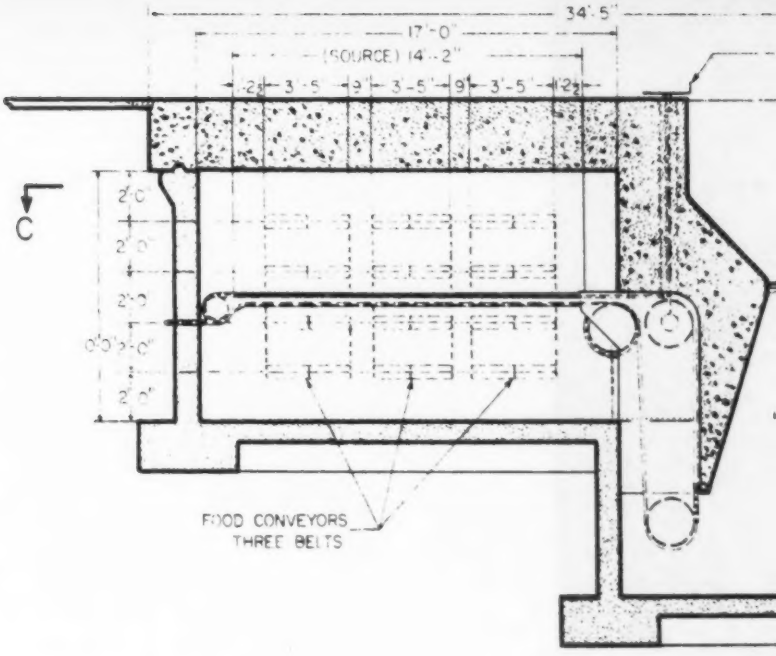
To permit processing of a variety of materials, the three conveyors have independent drive units.

C. CESIUM-137 GAMMA POWER AND PROCESSING CAPACITY

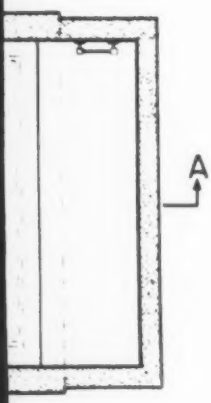
There are 86 tubes of CsCl in the radiation plaque with a total activity of 7.8×10^6 curies and a gamma power of 28.2 kilowatts when the source is new. The average gamma power over the five year use period is 26.6 kw. About 85 per cent of the gammas, or 22.6 kilowatts, escapes the source tubes and cooling water tank. Of this about 25 per cent can be usefully absorbed. Materials requiring irradiation to 2.5×10^6 reps could be processed at a rate of 23.3 tons per 24-hour day. The hold-up period for this exposure is 12 hours. This period could be reduced by almost a factor of two by using a fast-loading conveyor in



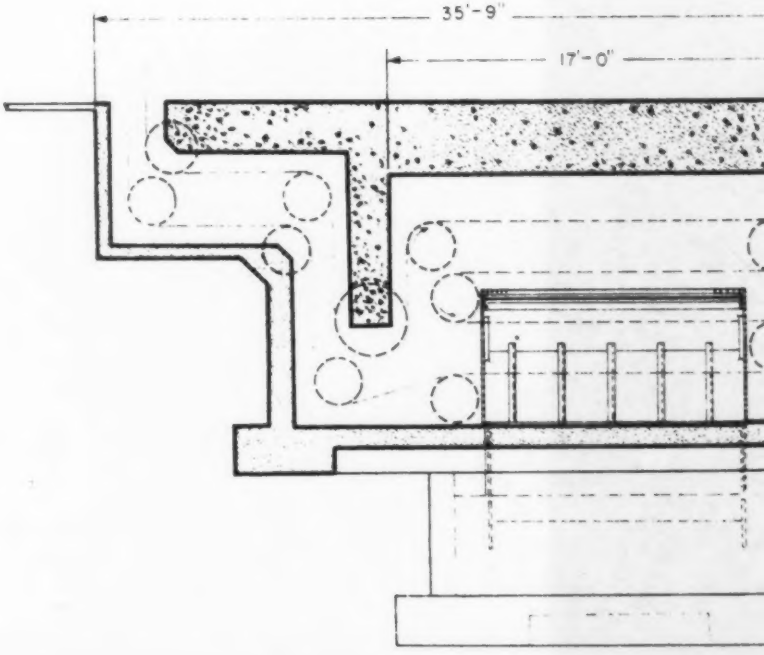
52249 O - 60 - pt. 1 (Face p. 526)



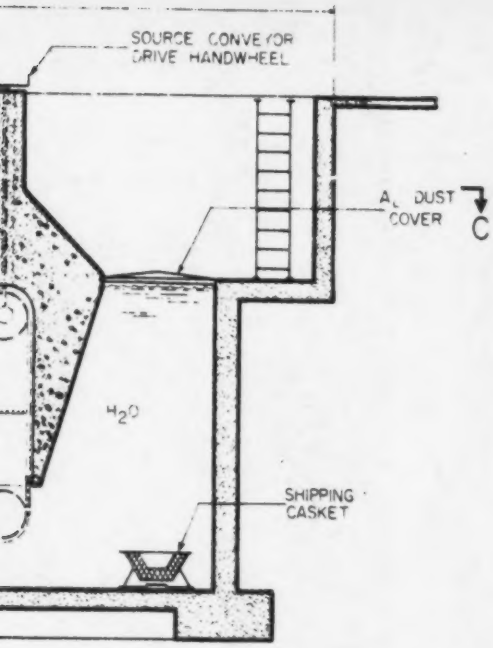
SECTION AA



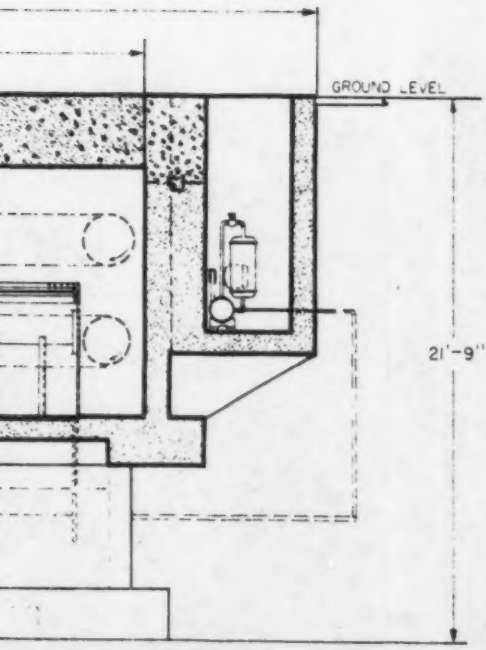
TEST SECTION



SECTION BB



A



B

Fig. 19. Radiation Cell for Cesium-137 Source

the la
radia
maxi

D. C

of thi

This
of the

the co
which
the ot

are ob

Annua
(at 90

Capita
(at 15

Sectio

cooled

the labyrinth which would load the slowly-moving conveyor that travels around the radiation plaque. The minimum exposure is 1.6×10^4 reps obtained with the maximum conveyor speed of 30 feet per minute.

D. COST ESTIMATES FOR THE CESIUM-137 PROCESSING FACILITY

The estimates of capital and operating costs are limited, for the purposes of this study, according to the discussion of Section I, page 8.

The estimated cost of the radiation cell and associated equipment is $191,000. This figure does not include the cost of the cesium source. The estimated cost of the food-handling conveyors is $196,000, giving a total investment of $387,000.

The only special operating costs associated with this radiation source is the cost of replenishing the source. This factor is considered in Section X in which an estimate is made of the price of cesium at which it could compete with the other radiation sources.

With the above investment figure, the following partial unit cost estimates are obtained.

	Exposure		
	2.5×10^6 reps	10^5 reps	1.6×10^4 reps (min)
Annual Through-put (at 90% Plant Factor)	1.53×10^7 lbs/yr	3.83×10^8 lbs/yr	2.39×10^9 lbs/yr
Capital Costs (at 15% per year)	0.379¢/lb	0.0152¢/lb	0.0024¢/lb

These costs are compared with those of the other radiation sources in Section X.

VI. RADIATION FACILITY USING SODIUM-24

Several of the reactors which have been proposed for power production are cooled with liquid-sodium metal. The sodium so used becomes radioactive,

emitting gamma rays of sufficient energy to be attractive for radiation processing. Use of a side stream of the coolant for this purpose would not disturb the reactor operation and makes the gamma rays available as a byproduct.

A. SELECTION OF SODIUM-COOLED REACTOR

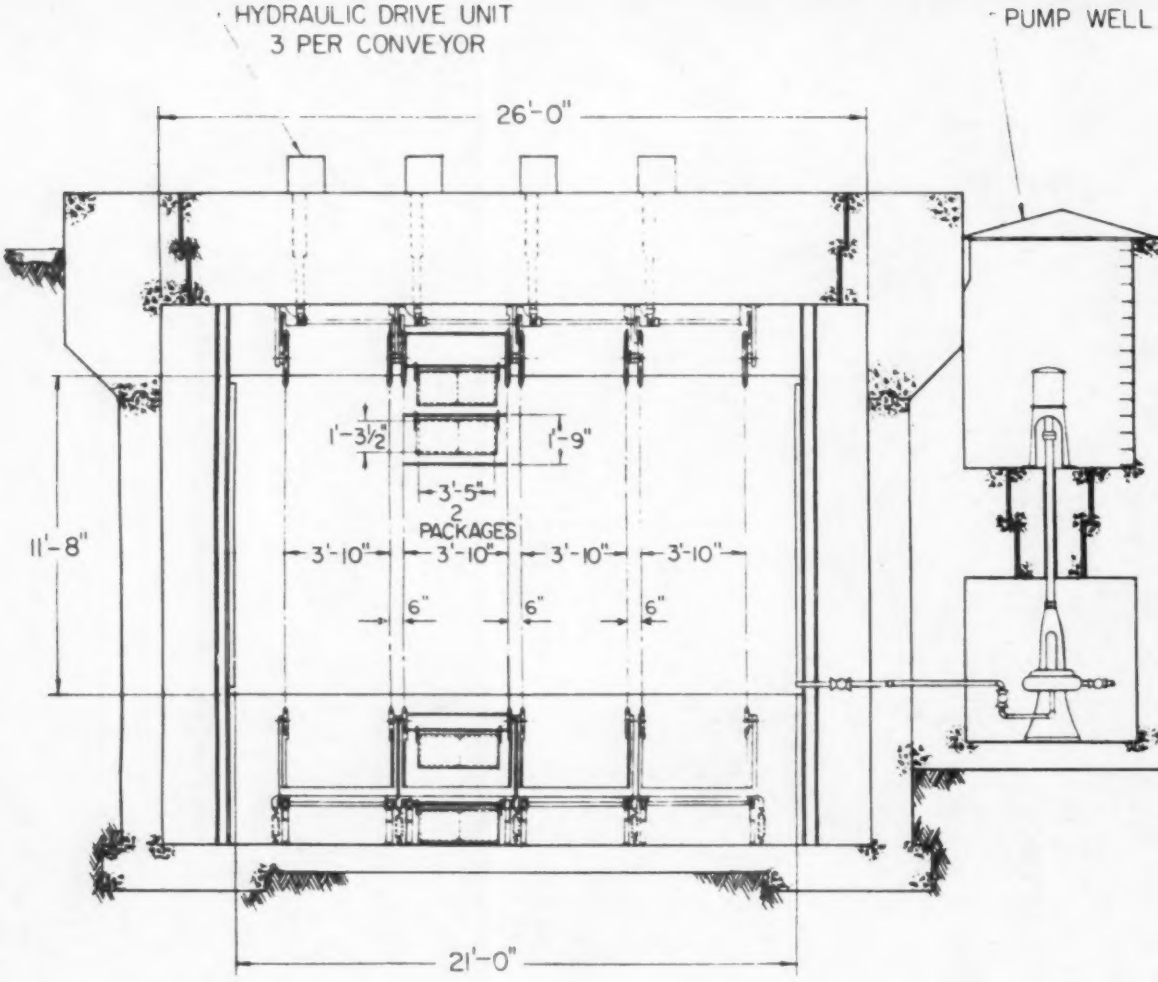
There are three types of sodium-cooled reactors under development in this country. These are the Sodium Graphite Reactor (SGR), the Submarine Intermediate Reactor (SIR) and the Experimental Breeder Reactor (EBR). For the radiation source it is desirable to have as high a specific activity, disintegrations/sec-cm^3, as possible. None of the reactors have been designed with this consideration in mind; in fact, minimum coolant activity is desirable from the viewpoint of the power-plant designer.

In the SGR design there are large pools of sodium external to the reactor core. These reduce the specific activity since the total activity is determined by the rate of neutron absorption in the sodium contained in the core.

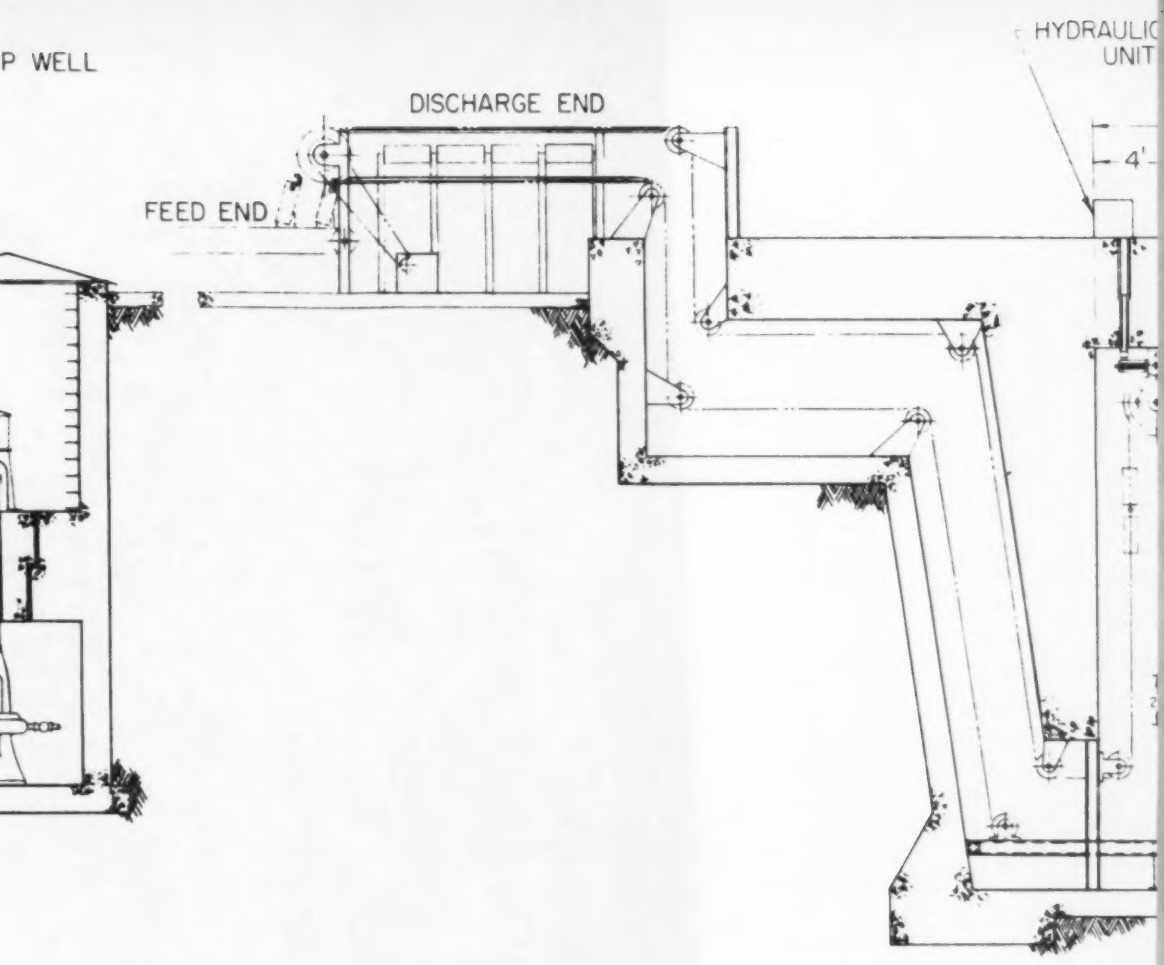
Another consideration in the selection of a reactor as a source of radioactive sodium is the volume of sodium in the cooling system. The volume of sodium required for the radiation plaques must be added to the total, reducing the specific activity. If the volume of the cooling system is small, the reduction in activity is appreciable.

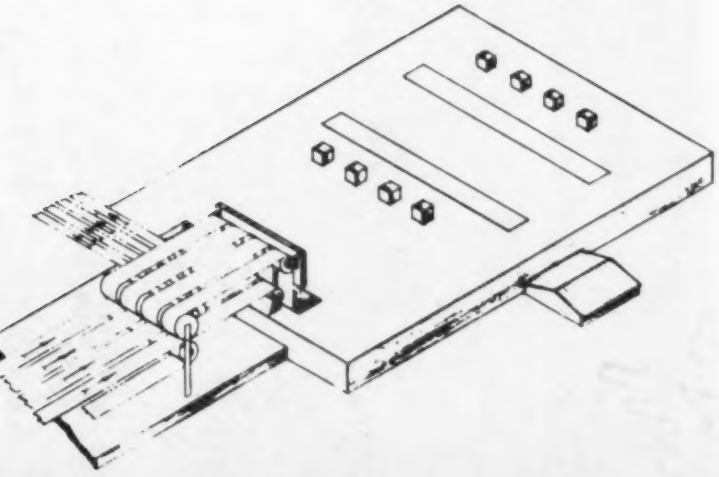
The specific activity of the sodium coolant in the SGR will be about 1/3 curie per cm^3 when the reactor is operating at full power. With an assumed plant factor of 70 per cent, equivalent to full power operation 70 per cent of the time, the specific activity will average 0.23 curies per cm^3. The volume of the cooling system in the SGR is about 2450 ft^3. The additional volume required for the radiation facility presented in this section is about 200 ft^3; this dilution reduces the specific activity to 0.21 curies per cm^3.

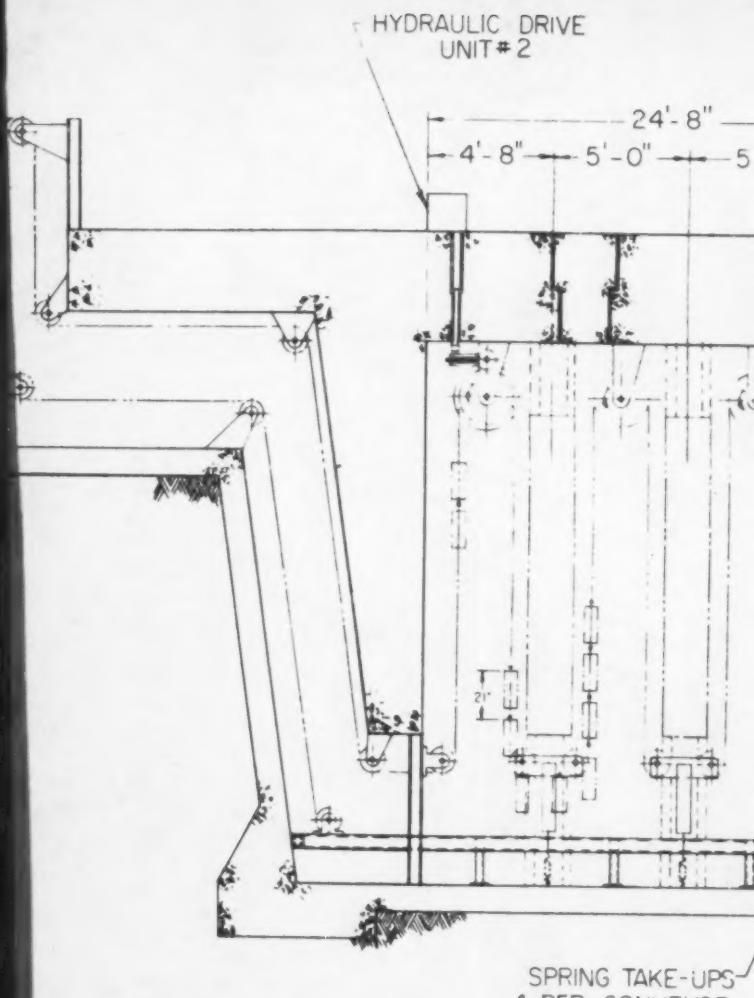
In the SIR, the specific activity has been estimated at 0.6 curies per cm^3 when the reactor is operating at full power. The volume of the cooling system is only a few hundred cubic feet however, and the dilution resulting from the addition of enough sodium for the radiation source would reduce the specific activity to a value near that of the SGR.


HYDRAULIC DRIVE UNIT
3 PER CONVEYOR
PUMP WELL
26'-0"
1'-3½"
1'-9"
3'-5"
2
PACKAGES
11'-8"
3'-10"
3'-10"
3'-10"
3'-10"
6"
6"
6"
21'-0"

P WELL






HYDRAULIC DRIVE
UNIT # 2
24'-8"
4'-8"
5'-0"
5
SPRING TAKE-UPS
4 PER CONVEYOR

Fi
ot

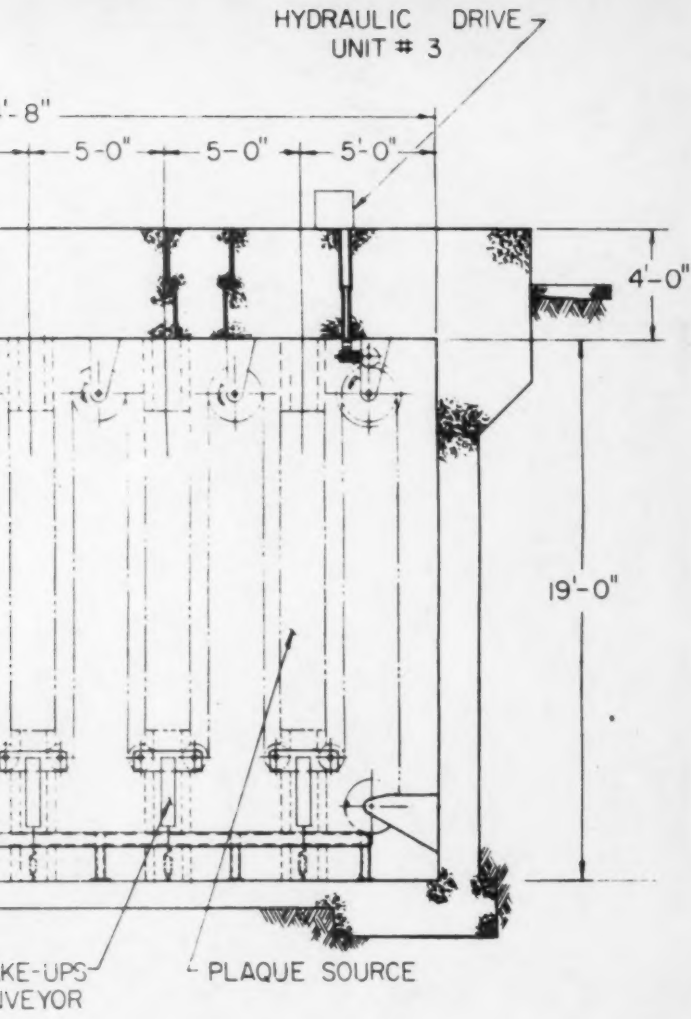
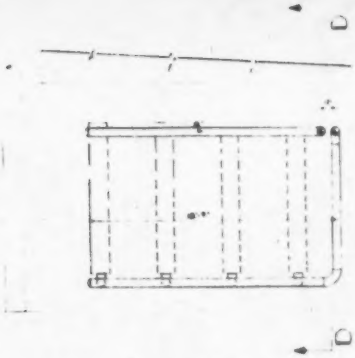
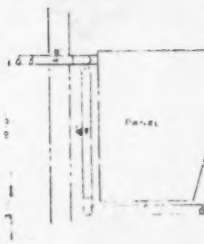


Fig. 20. Ra[illegible]ation Cell for Use of Sodium-24

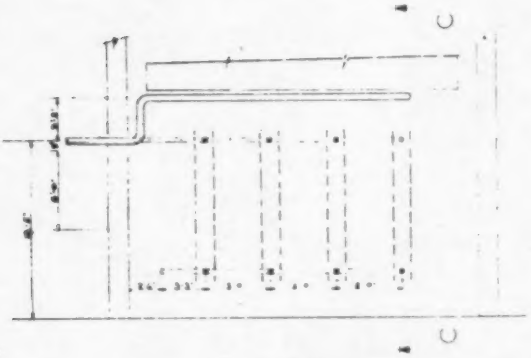
52249 O-60-pt. 1 (Face p. 529) No. 1



SECTION A-A
COOLING SYSTEM

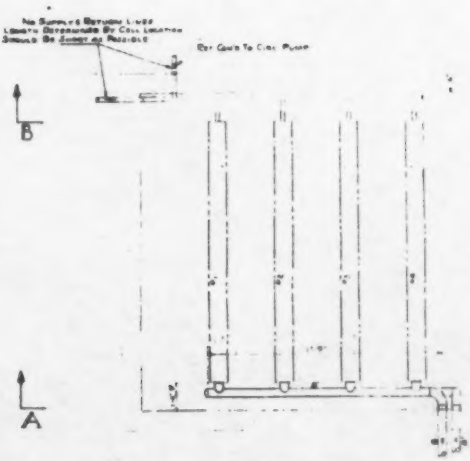


SECTION D-D
COOLING SYSTEM



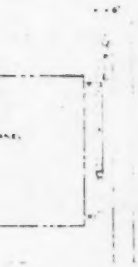
SECTION E-B
NO SYSTEM

SECTION C-C
NO SYSTEM

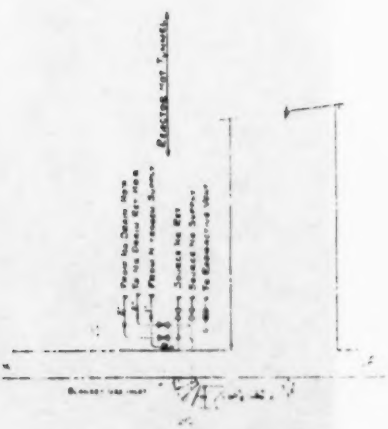


PLAN - PIPING
FOR PANELS

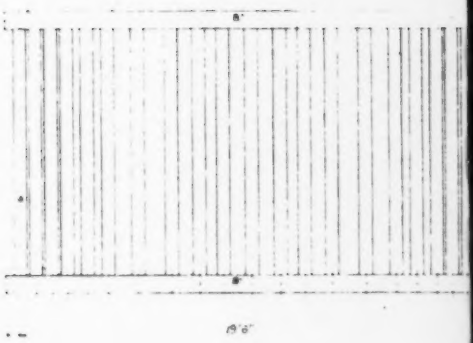
SECTION D-D



SECTION C-C

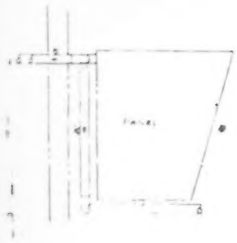


A Typical Installation Showing Piping Point of Take Off Determined By Coil Location

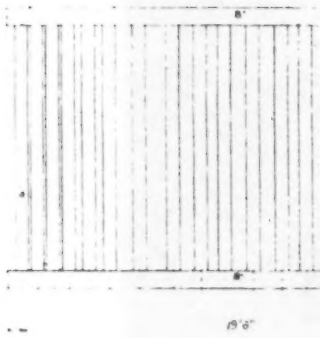


SOURCE PANEL
4 REQD

NOTE
1. Heads To Be Hung From of Bar At Ceiling By Four Hangers Out From Tubes Rolled Flat
2. Lower Jacket To Have Inlet Gas Inlet & Cold Tube Vent
3. Lower Jacket To Have Electric Heaters To Be Detailed By Others

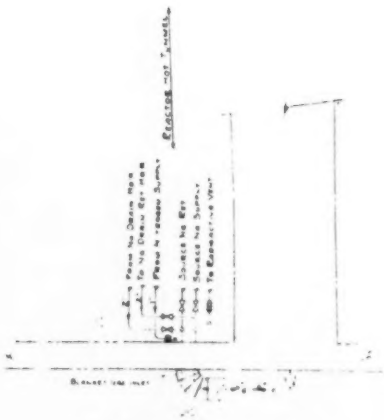


SECTION D-D



SOURCE PANEL

SECTION C-C



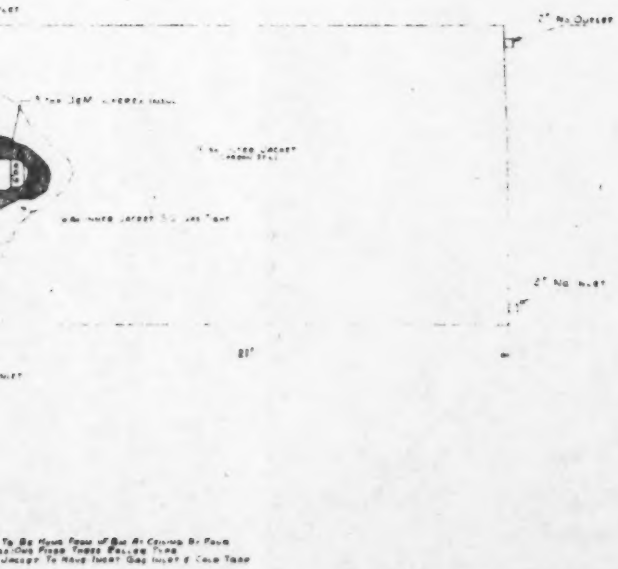


Fig. 21. Sodium Source Plaque and Auxiliary Piping

52249 O - 60 - pt. 1 (Face p. 529) No. 2

is u
acti

desi
abs
coul
elec
cell

the
for

B.

abs
emi
dia
lar
foo
pre
par
Sec

the
pow
the
wa
the

C.

cel
vie

3226); 0-80-pp. 1 (Trace p. 329) No. 1

The EBR is a low-power machine designed for experimental purposes. It is unlikely that a full-scale version would exceed the above figures for specific activity.

To maximize the specific activity of the sodium, the reactor should be designed with this function in mind. For example, in the SGR most of the neutron absorption is in the sodium which cools the graphite moderator. If this coolant could be kept separated from the large-volume system which cools the fuel elements, the specific activity could be as high as 5 curies/cm^3. A radiation cell using such material would be compact and relatively inexpensive.

Because the appropriate numbers were available for the SGR and since the alternatives offer no apparent advantages, the radiation facility was designed for use of sodium from the SGR.

B. RADIATION CHARACTERISTICS OF SODIUM-24

Natural sodium consists of the single isotope sodium-23, which upon neutron absorption produces sodium-24. The half life of sodium-24 is 15.06 hours; it emits two gammas of 1.37 Mev and 2.75 Mev in essentially 100 per cent of its disintegrations. These two gammas are sufficiently energetic for processing of large packages. The 2.75 Mev gamma is capable of producing neutrons in the food during radiation processing. These would come from the trace of deuterium present in the contained water. The number of neutrons produced is small compared to the number produced with the electron accelerator; as demonstrated in Section VIII-A, 2, neutron production should not be troublesome.

Since the sodium-24 must be produced as a byproduct to power production, the specific activity of the sodium will be dictated by the requirements on the power plant; the activity will be directly proportional to the reactor power. In the calculations of processing capacity, an average plant factor of 70 per cent was assumed. Sudden changes in reactor power will produce slow changes in the sodium activity because of its 15-hour half life.

C. DESIGN OF RADIATION FACILITY FOR USE OF SODIUM-24

1. Radiation Cell Design and Flow Diagram - The sodium in the radiation cell is contained in four banks of tubes 10 feet high by 20 feet wide. Over-all views of the cell are shown in Fig. 20. Details of the plaques appear in Fig. 21.

32247 U-60-pt. 1 (Face p. 529) No. 1

The tubes are insulated to minimize heat transfer to the cell from the hot liquid sodium. The insulation has a helium atmosphere which is monitored for activity; any activity present would indicate a sodium leak. Around the insulation is a thin, steel secondary container; outside of the secondary containers is a jacket to provide a duct for cooling air.

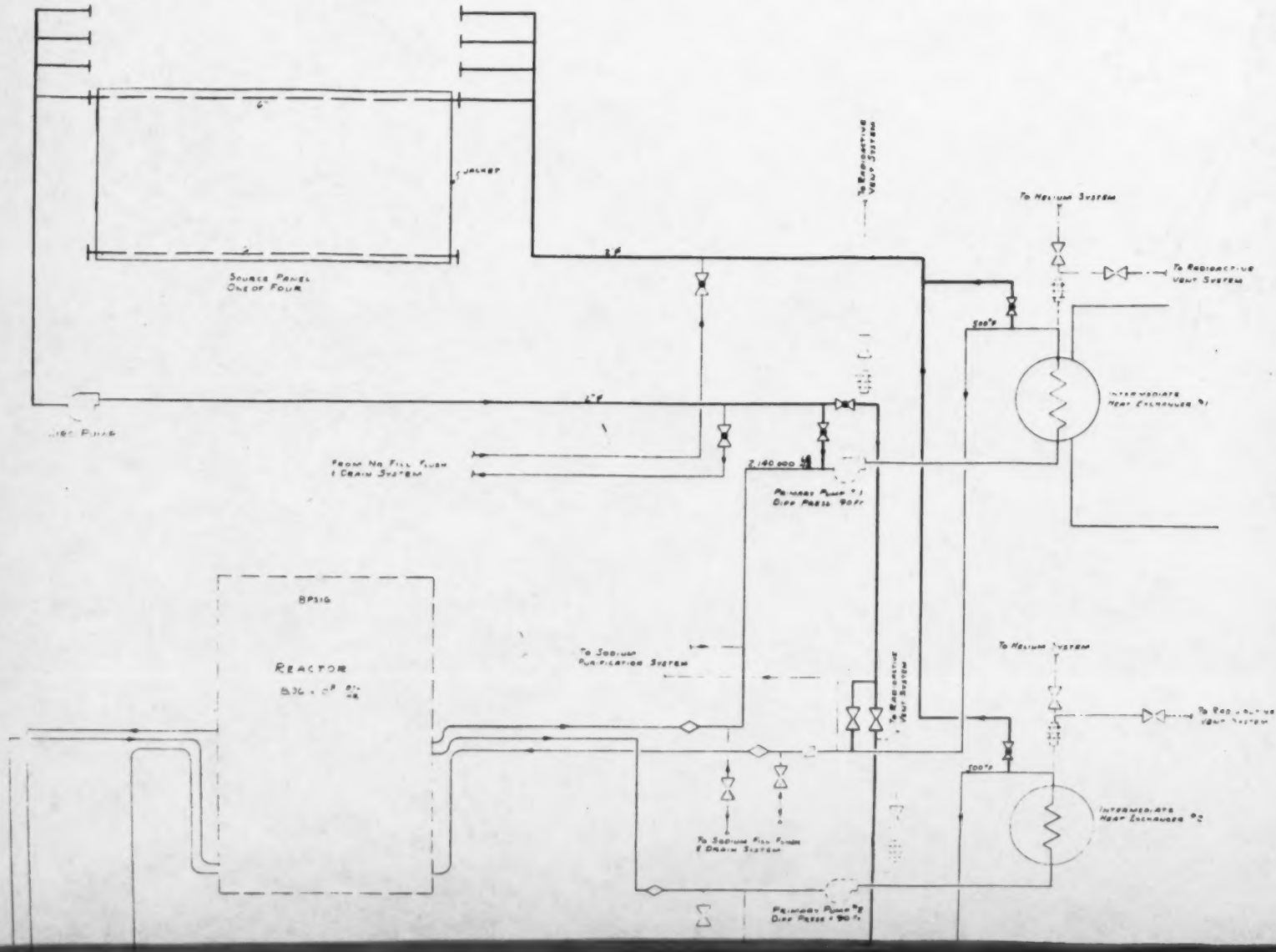
The main piping in the primary cooling system of the SGR is shown in Fig. 22. The reactor is designed to operate with a minimum of two of the three primary coolant loops, each of which contains a pump and heat exchanger. Taps for sodium for the radiation plaques are made on two of these loops, as indicated in Fig. 22. The sodium is taken from the "cold" side of the heat exchanger where the sodium is at its minimum temperature of 500° F. It is circulated by means of a small pump through the four gamma radiators and returned to the cold leg of the primary cooling loop. The flow of 100 gpm through the radiators is negligible compared to the flow in the primary loop. At this flow rate, the sodium is changed in the four radiation plaques about four times per hour.

The sodium supply to the radiation cell is divided into four lines, each line supplying a radiation plaque. The sodium enters the header at the top of the tube bank, flows downward through the tubes, then is collected in the lower heater and pumped back to the primary loop. The velocity of the sodium in the tubes is less than one foot per minute; with downward flow, there is no problem of stagnation. Differences in sodium velocity from one tube to the next are unimportant because of the 15-hour half life of sodium-24.

When it is necessary to enter the radiation chamber, the sodium is pumped from the plaque and replaced with helium. The system is then flushed with fresh sodium to remove the activity which clings to the walls. In this procedure, the reserve coolant in the reactor cooling system would be used. The requirements for the radiation source are minor compared to those of the reactor.

2. Cooling and Containment - The main problem in cooling the sodium tubes is to avoid transferring heat from the thermally-hot sodium to the processing cell. To minimize transfer, the sodium tubes are covered with 3-1/2 inches of insulation. Outside of the insulation is a thin-wall secondary container. Around the secondary container a cooling annulus is provided for air circulation. The air is cooled in a 10-ton refrigeration unit.

52249 O -60 -pt. 1 (Face p. 530)



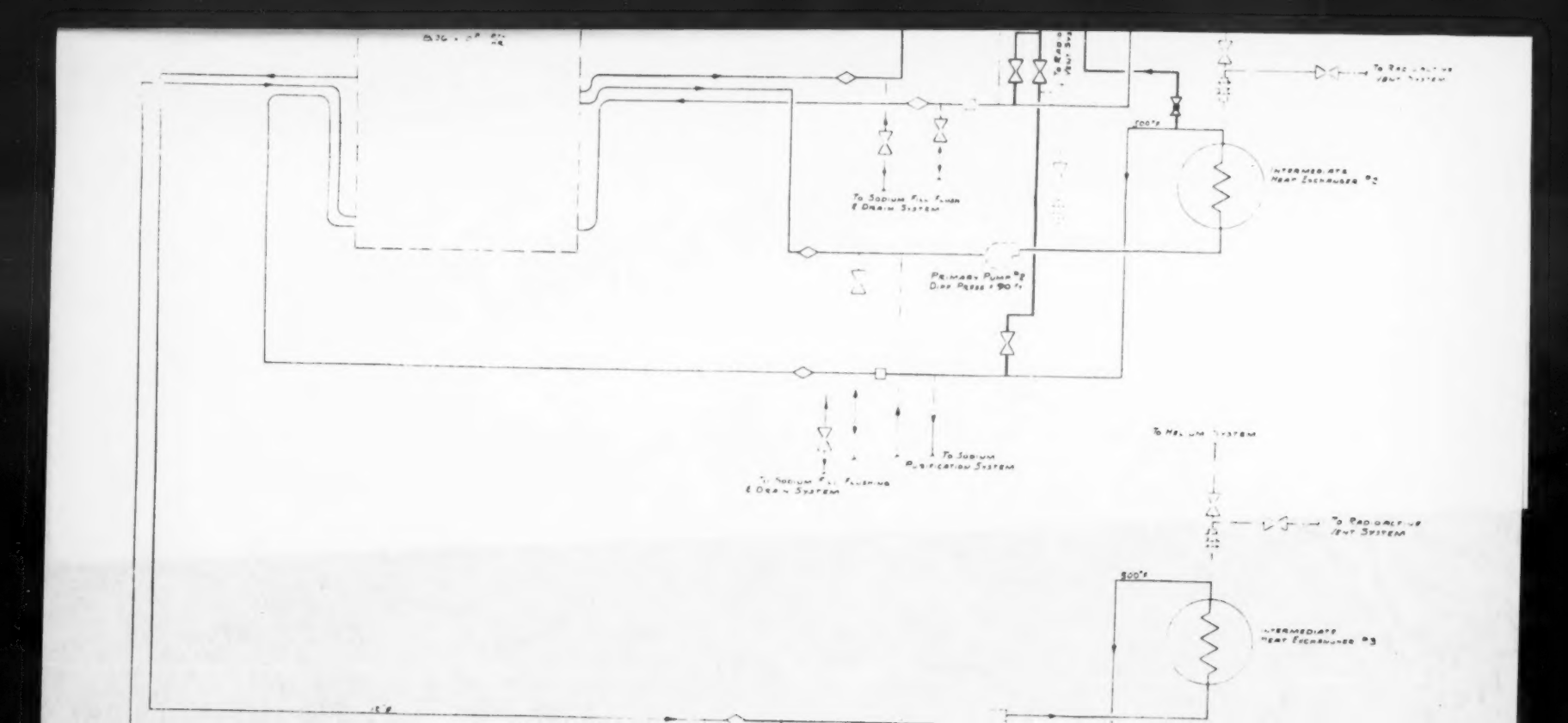

To Sodium Fill Flushing & Drain System
To Sodium Purification System
To Helium System
To Radioactive Gas Waste System
Intermediate Heat Exchanger No 2
Intermediate Heat Exchanger No 3
Primary Pump No 2 Diff Press 180 ft
700°F
800°F

Fig. 22. Sodium Supply System

detec
leak,
and t
woul
reac

Ther
The
of th
belts

are 4
boxe
four
of pl
ends

simu

D. C

of 19
the v
speci
react
With
of wh
abso

24.8
expos
figur

Leaks of sodium from the tube bank into the secondary container would be detected by monitoring the helium atmosphere around the tubes. In event of a leak, the plaque would be drained and flushed, the spill would be allowed to decay and the plaque could be removed for repairs. Radioactive sodium from the plaque would be stored in the tanks provided for the reactor. Gases are vented into the reactor gas system.

3. Food-Handling Conveyor - The conveyor system is shown in Fig. 20. There are four independently-driven belts each wide enough for two V3 boxes. The conveyor makes two passes across each face of the four plaques. Because of the length of the conveyor, three drive units are required on each of the four belts.

The spacing between baskets is 52 inches by 21 inches. The two V3 boxes are 41 inches by 15-1/2 inches so that coverage of the radiation plaques by V3 boxes is about 58 per cent in the region covered by conveyor belts; because the four belts cover only 202 of the 240 inches of plaque width, the overall fraction of plaque coverage is 49 per cent. The radiation field is not uniform near the ends of the plaque.

With the independent conveyors, four different materials can be processed simultaneously.

D. GAMMA POWER AND PROCESSING CAPACITY

The volume of sodium in each of the plaques is 48.5 cubic feet for a total of 194 cubic feet (5.5×10^6 cm^3). This represents an increase of 7 per cent in the volume of the primary coolant loops of the SGR, and reduces the average specific activity to 0.21 curies/cm^3; this figure assumes 70 per cent of full reactor power. The total source strength of the four plaques is 1.16 megacuries. With 4.14 Mev of gamma energy per disintegration, the gamma power is 28.4 kw, of which 85 per cent escapes the radiation plaques. Six kilowatts can be usefully absorbed in process material.

With a sterilization exposure of 2.5×10^6 reps, the facility capacity is 24.8 tons per day with continuous operation. The corresponding figure for exposure to 1.5×10^4 reps is 4140 tons per day. At full reactor power these figures would be increased 43 per cent. The conveyor speed need not be rapidly

adjustable since the 15-hour half life of the sodium would provide a slow varying source strength even with power oscillations in the reactor.

The exposure time required for 2.5×10^6 reps is about 28 hours. The minimum exposure, obtained with the maximum conveyor speed of 30 feet per minute is 1.3×10^4 reps. The time required for this exposure is 9 minutes.

E. COST ESTIMATES FOR THE SODIUM-24 PROCESSING FACILITY

The estimates of capital and operating costs are limited, for the purposes of this study, according to the discussion of Section I, page 8.

The estimated cost of the radiation cell and associated equipment is $407,000. The estimated cost of the four-belt conveyor system is an additional $296,000.

There are no special operating costs associated with this source; use of the thermally-cold sodium has no effect on the operation of the power plant.

With the above investment estimates, the following partial unit-processing costs are obtained:

	Exposure		
	2.5×10^6 reps	10^5 reps	1.5×10^4 reps
Annual Through-put (at 90% Plant Factor)	1.62×10^7 lbs/yr	4.04×10^8 lbs/yr	2.69×10^9 lbs/hr
Capital Costs (at 15% per year)	0.648¢/lb	0.0260¢/lb	0.0039¢/lb

These costs are compared with those of the other radiation sources in Section X.

VII. RADIATION FACILITY USING A REACTOR-ACTIVATED GAMMA EMITTER

A gamma source can be produced by exposing an appropriate material to the neturon flux in a nuclear reactor. This is the means by which the several

cobalt-60 sources now in use have been produced. These sources were activated in reactors which were designed for other purposes and which therefore are not efficient for the process.

A considerable gain in efficiency can be made by building a reactor expressly for this purpose. Such a reactor should be built at the site of the food-processing plant to avoid costly transportation of radioactive materials. In this situation, a fluid which can be pumped from the reactor to the radiation cell is attractive from the viewpoint of handling ease.

A. CHOICE OF MATERIAL FOR ACTIVATION

In choosing a material to activate in the reactor, the important considerations are its activation cross section, half life, the gamma energy available per disintegration, and the individual photon energy. Two materials which appear promising for this application are manganese and indium in aqueous solution. Manganese has the advantage of occurring naturally with only one isotope, manganese-55, leading upon neutron absorption to a single radioactive isotope, manganese-56. The half life is 2.58 hours and three gammas are emitted. The gamma energies and average number of photons per disintegration are as follows: 2.06 (20%), 1.77 (30%), and 0.822 (100%). The average gamma energy per disintegration is 1.76 Mev. The activation cross section for thermal neutrons is 13.4 barns.

Indium has the advantage of a higher activation cross section so that neutrons are more readily absorbed. There are two isotopes of natural indium-113 and -115, each producing two activities upon neutron absorption. The important activity for our purposes is due to indium-116m, which has a half life of 53.9 minutes. This isotope emits six gammas of energies: 2.09 (25%), 1.487 (21%), 1.274 (75%), 1.085 (54%), 0.406 (25%), and 0.137 (3%) Mev. The average gamma energy per disintegration is 2.47 Mev. The other three activities have half lives of 13 seconds, 72 seconds and 49 days; these activities are unimportant as sources of gamma rays. The activation cross section for the production of indium-116m with thermal neutrons is 145 barns; because of the production of the unimportant activities, only 73 per cent of the neutron absorptions in indium lead to the desired isotope. Primarily on the basis of its large cross section, indium was selected as the material for activation.

B. REACTOR SYSTEM

A gamma source produced by a reactor which has no other function must support the entire installation and is therefore in a relatively poor competitive position. Since this fact can be quickly established without a detailed study, no preliminary design effort was made on such a gamma facility in this study. However, considerations of availability of the gamma source and interest in short food-irradiation periods make this system attractive for a food-processing pilot plant; this source can be made available more quickly than any of the other gamma sources, and a high specific activity with an associated high-intensity radiation field can readily be obtained.

For the purpose of cost comparisons with the other radiation sources, a cost estimate has been made for a reactor - gamma facility for which conceptual design and performance figures were obtained in a study at Oak Ridge National Laboratory.[8] The performance figures are taken directly from the Oak Ridge study; the cost estimates were prepared at Atomics International for reasons of consistency.

In the Oak Ridge study both manganese and indium were considered for the material to be activated. Several possible configurations of the reactor core were developed. One of the more promising indium systems was selected for cost estimating.

The reactor core is of the type used in the Materials Testing Reactor at Arco, Idaho, and consists of uranium - aluminum alloy fuel elements, clad in aluminum and cooled with water. The indium, in a sulfate solution in water, is activated in a blanket around the reactor core. The solution is pumped through two plaques in the radiation cell.

All of the performance data in the following paragraph are taken from the Oak Ridge study.

The reactor thermal power is 31 megawatts of which 2 per cent, or 620 kilowatts, is generated in the blanket solution. The core cooling water rejects heat to a secondary water system and cooling tower. The heat generated in the blanket solution rejects heat to the same system in a separate heat exchanger. The core water system is of aluminum; the solution system is of welded stainless steel with a zirconium blanket tank in the reactor. The Oak Ridge calculations predict 0.319 atoms of indium-116m produced per fission. Since some of the

solution is in the blanket and piping system, not all of the gammas from the indium are available for radiation processing; a figure of 72 per cent is given for the fraction of solution in the radiation plaques.

C. DESIGN OF RADIATION FACILITY USING ACTIVATED INDIUM

1. Radiation Cell Design - No layouts were made for the radiation cell which would use this source of gammas. It would be similar to the cell for the use of liquid sodium, Fig. 20, but would contain two source plaques rather than four. The radiation plaques consist of a bank of steel tubes 12 feet wide and 7-1/2 feet high. Provisions are made for draining and flushing the plaques to permit maintenance activities in the radiation cell.

2. Cooling and Containment - Heat from the source material is rejected to a heat exchanger external to the radiation chamber. To protect the radiation cell and food materials in the event of a leak in the radiation plaques, secondary containers are provided. These consist of thin-wall steel tanks with an air passage between the plaque and tank; the air is monitored for radioactivity. If a leak occurs, the solution is drained from the plaque and secondary container. After flushing the system, repairs can be made.

3. Food-Handling Conveyor - The conveyor for this radiation cell is similar to that in the cell of Fig. 20. There are three independent belts, two of which are wide enough to accommodate two of the V3 boxes while the third accommodates one box. Independent drive units permit the processing of materials requiring different exposure periods.

D. GAMMA POWER AND PROCESSING CAPACITY

At 31 megawatts the fission rate in the reactor core is 1.01×10^{18} fissions per second. With the production of 0.319 atoms of indium-116m per fission, the steady-state activity in the indium solution is 3.2×10^{17} disintegrations per second, each producing 2.47 Mev of gamma energy. With 72 per cent of the solution in the radiation plaques, the gamma power of the plaques is 91.5 kilowatts. The use of volume fraction is permissible since the cycle time of the solution is short compared to its half life. About 80 per cent of the gamma power, or 73 kilowatts, escapes the plaques; of this, 25 per cent can be usefully absorbed. The processing capacity of the facility is 75 tons per 24-hour day of a material

irradiated to 2.5×10^6 reps. The processing time required for this exposure is 3.8 hours. The minimum exposure, obtained with the maximum conveyor speed of 30 feet per minute, is 6.2×10^4 reps. Processing time for this exposure is about 6 minutes.

E. COST ESTIMATES FOR THE ACTIVATED-INDIUM FACILITY

With no design effort beyond the conceptual stage for the reactor and radiation cell, it was necessary to obtain cost estimates by means of extrapolation from data on similar equipment. The reactor is similar to a 25-megawatt reactor designed for research purposes. With minor extrapolations in the cooling system and deletion of the experimental facilities on the research machine, it was possible to obtain a reasonably accurate cost estimate for the food-irradiation reactor.

The cost of the radiation cell was obtained by extrapolations from the cells designed for the other gamma sources for which layouts and cost estimates were made. These cost figures are therefore considerably less reliable than those obtained for the other sources. Since the cost of processing foods would be high with this system and because the objective of the study is to determine the most economic system, these figures are deemed adequate.

With the figures thus obtained, the estimated cost of the reactor is $2,500,000. This figure does not include the cost of the fuel elements which would contain several kilograms of uranium-235. A gas-tight building of the type used for research reactors is included in the reactor cost.

The estimated cost of the radiation cell and associated equipment is $192,000. The cost of the conveyor system is an additional $178,000, giving a total capital investment estimate of $2,870,000.

The reactor fuel is an important item in the cost of food processing. The 31-megawatt reactor would require about 40 grams per day of uranium-235. Assuming $25 per gram, a figure quoted[9] for the U-235 contained in 20 per cent enriched uranium, the cost of providing fuel for the reactor is about $33 per hour. This figure is optimistic for two reasons: (1) the fuel enrichment required to give the reactor performance figures quoted in Section VII-D is much higher than 20 per cent, and (2) the figure assumes 100 per cent burn-up of the fuel

without chemical processing. The fuel cost figure might easily be low by a factor of two.

The cost of the reactor operating crew is an additional special cost unique to this radiation source. This cost is neglected; its inclusion would not change the conclusions of this report.

With the above estimated costs, the following partial unit processing costs are obtained:

	Exposure		
	2.5×10^6 reps	10^5 reps	6.2×10^4 reps (min.)
Annual Through-put (at 90% Plant Factor)	4.93×10^7 lb/yr	1.23×10^9 lb/hr	1.99×10^9 lb/yr
Capital Costs (at 15% per year)	0.874¢/lb	0.0349¢/lb	0.0216¢/lb
Minimum Reactor Fuel Cost ($33/hr)	0.528¢/lb	0.0211¢/lb	0.0131¢/lb
Partial Total	1.402¢/lb	0.0560¢/lb	0.0347¢/lb

These costs are compared with those of the other radiation sources in Section X.

VIII. RADIATION FACILITY USING AN ELECTRON ACCELERATOR

Several types of electron accelerators can be used for radiation processing; these include the Van de Graaff, resonant transformer, capacitron and the travelling-wave linear accelerator. The most promising of these appears to be the linear accelerator; in this machine electron-beam powers of several kilowatts can be obtained with electron energies of tens of Mev.

A. CHARACTERISTICS OF ELECTRON IRRADIATION

1. General Discussion - Some discussion of electron penetration and the nature of the beam from a linear accelerator was given in Section II-D. The

electron energy required for processing of materials of unit density in packages six inches thick is about 18 Mev, if the package is irradiated from both sides. With irradiation from one side only, the electron energy required is approximately doubled. The lowest possible electron energy is desirable to minimize machine cost and reduce X-ray production. The production of high-energy X-rays is undesirable since they cannot be efficiently utilized in processing, and because they produce activity in the food and conveyor equipment. This problem is discussed below. Irradiation from only one side also wastes electron-beam power since some of the beam passes completely through the process item when the electron energy is adjusted to give equal exposure rates at the entrance and exit surfaces.

Irradiation from both sides of the process item is therefore desirable. For processing of dry materials which do not shift in the container as the package is rotated, it is possible to use a single machine which irradiates first one side of the package then the other. For processing of packages containing liquids, it is necessary to expose both sides of the package simultaneously to avoid the possibility of under-exposure of some of the liquid. Radiation facilities are presented using both a single accelerator and two accelerators.

2. X-Ray Production and Induced Activity - One of the characteristics of irradiation with high-energy electrons is the production of bremsstrahlung or high-energy X-rays. The fraction of the electron beam power which is converted to X-rays depends upon the atomic weight of the material penetrated by the electrons and upon the incident electron energy. This is indicated in Fig. 23 in which curves of the fraction of electron energy which is converted to X-ray energy are presented for aluminum, copper and gold. These curves are reproduced from the data of C. W. Miller.[10]

The X-rays are produced with a continuous energy spectrum from zero up to the electron energy. The X-rays are troublesome for three reasons: (1) with the electron energies required for processing of foods, the high-energy X-rays produced are capable of producing radioactivity, through photo-neutron reactions in any material (except hydrogen) which is exposed to the electron beam, (2) the X-rays make it necessary to shield the processing facility, and (3) the high-energy X-rays are not readily absorbed in the process item; they penetrate the package completely, carrying away an appreciable fraction of the electron-beam power.

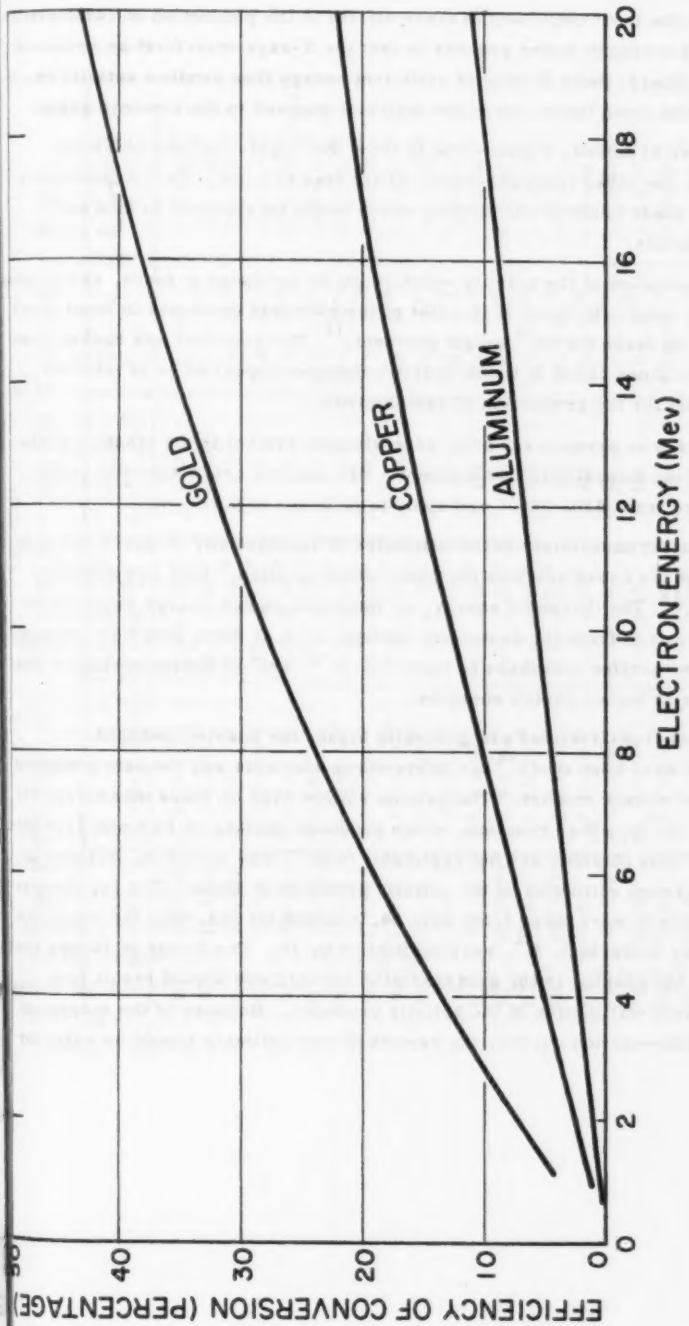


Fig. 23. Conversion Efficiency - Electron Energy to X-Ray Energy

Perhaps the most important of these effects is the production of radioactivity. The process is a second-order process in that the X-rays must first be produced by electron scatters; those X-rays of sufficient energy then produce activity by ejecting neutrons from the nuclei of the material exposed to the electron beam.

Two types of activity result - one is from the "light" nucleus which has lost a neutron, the other from absorption of the free neutron. Very approximate estimates are made below of the activity which might be expected in food and conveyor materials.

As an indication of the activity which might be produced in foods, calculations were made for meat. In Table II is a list of the elements contained in meat which are present to at least 5×10^{-5} weight per cent.[11] The elements are broken down into isotopes in those cases in which specific isotopes appear to be of interest as fertile nuclei for the production of radioactivity.

The figures in parentheses after each element symbol is the fraction of the isotope occurring naturally in that element. The neutron cross sections in the last column are from BNL-325[12] and apply to neutrons of 0.025 ev.

The greatest uncertainty in the estimates of radioactivity is due to the lack of knowledge of the cross sections for photo-disintegration. Data are available for deuterium.[13] The threshold energy, or minimum photon energy required for ejection of a neutron from the deuterium nucleus, is 2.23 Mev, which is unusually low. The cross section increases to about 2×10^{-27} cm^2 at approximately 4 Mev, then decreases at higher photon energies.

The (γ, n) cross sections are generally higher for heavier isotopes. Measurements have been made[14] for thirty-three elements and the data presented as a function of atomic number. The gamma source used on these measurements were from the $Li^7(p, \gamma)Be^8$ reaction, which produces photons of 14.8 and 17.6 Mev. The cross sections obtained are not applicable to an X-ray spectrum, but can be used to obtain rough estimates of the activity produced in foods. The (γ, n) cross sections of Table II were taken from Ref. 14, rounded off and, with the exception of the figure for deuterium, H^2, were multiplied by 10. The factor of 10 was used to account for the peaking in the cross-section curves, and should result in a considerable over-estimation of the activity produced. Because of the maximum in the (γ, n) cross-section curves, the results of this estimate should be valid for

TABLE II

ISOTOPIC CONTENT AND NUCLEAR CHARACTERISTICS OF MEAT

TABLE II

ISOTOPIC CONTENT AND NUCLEAR CHARACTERISTICS OF MEAT

Isotope	Weight Fraction	Atoms/cm^3 ($\times 10^{-24}$)	σ (γ, n) ($\times 10^{+27}$ cm^2)	Σ(γ, n) cm^{-1}	Σ_a (neutrons) cm^{-1}
H^1 (99.985)	0.10	6.02×10^{-2}	0	0	2.0×10^{-2}
H^2 (0.015)	1.5×10^{-5}	4.5×10^{-6}	(2)	9×10^{-9}	2.1×10^{-9}
C^{12} (98.89)	0.15	7.5×10^{-3}	3	2.3×10^{-5}	2.5×10^{-5}
C^{13} (1.11)	1.7×10^{-3}	7.9×10^{-5}	3	2.4×10^{-7}	4.0×10^{-8}
N^{14} (99.63)	0.03	1.3×10^{-3}	4	5.2×10^{-6}	2.3×10^{-3} (n,p)
O^{16} (99.59)	0.65	2.44×10^{-2}	5	1.22×10^{-4}	4.9×10^{-6}
Na^{23} (100)	4.2×10^{-4}	1.1×10^{-5}	30	3.3×10^{-7}	5.6×10^{-6}
Mg^{24} (78.6)	1.7×10^{-4}	4.3×10^{-6}	30	1.3×10^{-7}	1.4×10^{-7}
Mg^{25} (10.1)	2.1×10^{-5}	5.1×10^{-7}	30	1.5×10^{-8}	1.4×10^{-7}
Mg^{26} (11.3)	2.3×10^{-5}	5.3×10^{-7}	30	1.6×10^{-8}	3.2×10^{-8}
P^{31} (100)	1.8×10^{-3}	3.5×10^{-5}	70	2.5×10^{-6}	6.7×10^{-6}
K^{39} (93.1)	4.6×10^{-3}	7.1×10^{-5}	180	1.3×10^{-5}	1.3×10^{-4}
K^{40} (0.0119)	5.8×10^{-7}	8.7×10^{-9}	180	1.6×10^{-9}	6.3×10^{-7}
K^{41} (6.9)	3.4×10^{-4}	5.0×10^{-6}	180	0.9×10^{-6}	6.0×10^{-6}
Ca^{40} (96.97)	2.5×10^{-6}	3.8×10^{-8}	200	7.6×10^{-9}	8.4×10^{-9}
Fe^{54} (5.84)	1.8×10^{-6}	2.0×10^{-8}	400	8.0×10^{-9}	4.4×10^{-8}
Fe^{56} (91.68)	2.9×10^{-5}	3.1×10^{-7}	400	1.2×10^{-7}	8.1×10^{-7}
Fe^{57} (2.17)	7×10^{-7}	7.4×10^{-9}	400	3.0×10^{-9}	1.8×10^{-8}
Fe^{58} (0.31)	1.1×10^{-7}	1.1×10^{-9}	400	0.4×10^{-9}	2.8×10^{-9}
Zn^{64} (48.9)	2.3×10^{-5}	2.2×10^{-7}	600	1.3×10^{-7}	1.1×10^{-7}
Zn^{66} (27.8)	1.3×10^{-5}	1.2×10^{-7}	600	7.0×10^{-8}	-
Zn^{67} (4.1)	1.9×10^{-6}	1.7×10^{-8}	600	1.0×10^{-8}	-
Zn^{68} (18.6)	8.7×10^{-6}	7.7×10^{-8}	600	4.6×10^{-8}	8.5×10^{-8}
		TOTAL CROSS SECTIONS		1.68×10^{-4}	2.25×10^{-2}

all X-ray energies which might conceivably be produced in the processing of foods with electrons.

Using the data of Table II, the number of neutrons produced and the number of radioactive nuclei can be estimated. The following assumptions are made:

a. Meat, 50 pounds per V3 box, is irradiated from both sides simultaneously using two 50-kw beam accelerators emitting 20 Mev electrons.
b. The exposure received is 2.5×10^6 reps.
c. Seven per cent of the electron beam, or 3.5 kw per machine, is converted to X-rays. The average atomic number for meat is about 7.
d. The X-rays are all of 10 Mev. This is approximately the threshold energy for photo-neutron reactions in most of the elements in meat.
e. The X-rays are produced at the surface of the V3 box, and penetrate the 6-inch dimension of the box with no attenuation.
f. The neutrons produced by photo-neutron reactions are all absorbed in the meat, and the fraction absorbed in each isotope is proportional to the neutron cross sections of Table II; this assumes the neutrons produced are of low energy so that the thermal cross sections apply.

The important activities determined in this manner are listed in Tables III and IV. In comparing Tables III and IV, it is apparent that the initial activities due to the "light" nuclei are much greater than those produced by neutron absorption. This results from the fact that most of the neutron absorption is in hydrogen which produces no activity, and because of the relatively short half lives of the light nuclei.

The importance of these activities in terms of radiation tolerance for a consumer can be seen by comparisons with established tolerances.[15] Of the light nuclei, only C-11 is of importance. The maximum permissible amount of this isotope in drinking water is about 5×10^{-4} $\mu c/cm^3$, or about 18 dis/sec-cm^3. The maximum permissible amount in meat has not been established but should be at least as great as for drinking water. This activity level would be reached 3.4 hours after exposure if the activity estimate in Table III at t = 0 were realistic

TABLE III

RADIOACTIVITIES OF REPRESENTATIVE "LIGHT" NUCLEI

Isotope	Half Life	Activities (dis/sec-cm^3 of meat)				
		at t = 0	t = 1 min	t = 10 min	t = 1 hr	t = 10 hr
C^{11}	20.4 min	1.9×10^4	1.9×10^4	1.4×10^4	2.5×10^3	~0
O^{15}	11.8 sec	1.0×10^6	7.4×10^5	3.1×10^4	~0	0
Na^{22}	2.6 yr	4×10^{-2}	4×10^{-2}	4×10^{-2}	4×10^{-2}	4×10^{-2}
Mg^{23}	11.9 sec	1.1×10^5	3.4×10^3	~0	0	0
Zn^{65}	250 day	6×10^{-2}	6×10^{-2}	6×10^{-2}	6×10^{-2}	6×10^{-2}

TABLE IV

REPRESENTATIVE NEUTRON-INDUCED ACTIVITIES

Isotope	Half Life	Activities (dis/sec-cm^3 of meat)		
		t = 0	t = 1 day	t = 10 days
Na^{24}	15.06 hr	7.8	2.6	~0
P^{32}	14.30 day	0.4	0.4	0.3
K^{42}	12.44 hr	10.1	2.7	~0

Of the neutron-induced activities, P-32 is most important in terms of tolerance because of its half life. The maximum permissible amount of P-32 in drinking water is 2×10^{-4} $\mu c/cm^3$ or about 7 dis/sec-cm^3. Comparing this figure with those of Table IV, the neutron-induced activities appear to be unimportant.

An additional fact of interest in discussing permissible activity in foods is that the K-40 occurring naturally in meat has an activity of 0.15 dis/sec-cm^3.

Because of the assumptions made in these estimates of radioactivity, the figures obtained should be quite pessimistic. Recent measurements[16] of the activity in meat, after irradiation with electrons of approximately 30 Mev, indicate the above estimates of activity soon after exposures are too high by several orders of magnitude. These measurements are continuing.

An additional problem of activity resulting from the use of high-energy electron acceleration is that induced in those parts of the food-handling conveyors which are exposed to the electron beam. This problem can be minimized by using materials of low atomic weight such as beryllium or aluminum for these conveyor components. Low atomic weight is important because the production of X-rays is minimized and because the cross sections for photo-neutron reactions are lower with these materials.

As in the case of meat, estimates of the activity which might be expected in a conveyor are hampered by lack of cross-section data. Estimates of activities for pure aluminum and pure iron were made with the following assumptions:

a. The conveyor is an endless belt of aluminum or iron, one centimeter thick.
b. The speed is that required for processing meat to 2.5×10^6 rep; about 14 feet per minute.
c. The belt is 100 feet long; unloading takes place 40 feet of belt from the accelerator.
d. The belt is exposed on both sides simultaneously to the electron beams from 50-kw accelerators.
e. The X-rays are produced at the surface and penetrate the belt with no attenuation.
f. The photo-neutron cross sections used are those of Table II.

The estimated activities in the aluminum and iron are 9.2×10^8 and 2.9×10^7 dis/sec-cm^3, respectively, when the belt leaves the electron beam. The figure for iron is lower than that for aluminum because Fe-53 if the only important activity produced; it results from photo-neutron reactions in Fe-54, which is present to only 5.86 per cent in natural iron. The aluminum activity is due to Al-26 with a half life of 6.5 secs; the half life of Fe-32 is 8.9 minutes, so that the activity does not vary appreciably around the conveyor loop.

The estimated activities in the Al and Fe at the conveyor unloading area, assumed to be 40 feet of belt from the accelerator, are 5.6 and 2.4×10^7 dis/cm^3-sec, respectively. The aluminum activity has almost disappeared at this point. The corresponding exposure rates at the surface of the belts are 6×10^{-3} mr/hr and 27 r/hr for the aluminum and iron, respectively.

These estimates are optimistic in that they assume pure materials; alloying materials and impurities could increase the estimates considerably. They are pessimistic in that the cross sections are probably too high and a continuous belt of material was assumed; the actual conveyor would expose only small parts to the electron beam.

The question of conveyor activity can best be answered with experiments. Use of aluminum in those parts of the conveyor which are exposed to the electron beam would probably make a single, continuous conveyor system feasible. Two types of conveyors are considered in this study. The facility which uses a single accelerator also uses a single conveyor, which carries food packages from the loading zone through the labyrinth and electron beam and back to the loading zone. The facility designed for the use of two machines has a two-conveyor system; one conveyor carries packages from the loading zone into the processing cell and a second conveyor carries the packages through the electron beam. The latter conveyor is confined to the shielded processing chamber. Views of these two systems appear in Fig. 24 and 25.

3. Production of Ozone - An additional problem with the accelerator is the production of ozone in the electron beam. If the radiation cell is at room temperature it is possible to use a simple hood and exhaust fan to remove ozone from the area. However, with a refrigerated cell this procedure would require a large refrigeration unit; chemical removal is more attractive.

An estimate of the ozone production rate can be made by computing the energy lost in oxygen by the electron beam. If it is assumed that all of the atomic oxygen formed is used in the production of ozone, i.e., that there is no recombination to form O_2, an upper limit on ozone production can be obtained. The dissociation of O_2 into atomic oxygen requires the absorption of 59.1 kg-cal per mole of atomic oxygen produced. The formation of ozone is also an endothermic reaction requiring 34 kg-cal per mole. The minimum energy requirement for the production of one mole of ozone is therefore 93.1 kg-cal (Ref. 17) or 389 kw-sec per mole.

Assuming 20 Mev electrons and a path length in air which averages 70 cm (to food package or to beam catcher when beam falls between packages), about 1.7 per cent of the electron beam energy is absorbed in air. With a 50-kw beam this is 0.835 kw, of which 0.194 kw is absorbed in oxygen. The ozone production based on the above assumptions is 1.8 moles, or 40 liters, per hour.

Ozone can be reduced to O_2 using oxides of manganese, lead, cobalt, iron, and silver or by several metals including silver, palladium and platinum. In some cases the material is used only as a catalyst; typical reactions are as follows:[17]

$$2Ag + O_3 \longrightarrow Ag_2O + O_2$$

$$Ag_2O + O_3 \longrightarrow 2Ag + 2O_2$$

Similar reactions are possible with manganese dioxide and lead dioxide. A hood system over the electron beam circulating the air to such a catalyst bed appears to be an inexpensive way of keeping the ozone concentration in the radiation cell at tolerable levels.

4. Relationships Governing Processing Variables - Because of the lower cost per kilowatt of beam power with the large accelerators, it is advantageous to use as large a machine as possible. The permissible beam power depends upon the required exposure and the maximum conveyor speed. The conveyors designed for the processing facilities of the next section cannot be operated faster than 30 feet per minute.

The electron beam from the linear acceleration is not continuous but is pulsed so that the electrons arrive at the package in bunches. The beam power

is varied by changing the pulse repetition rate. With present machines, possible pulse repetition rates are multiples of 60 cps starting with 30 and going as high as 360 cps. A machine rated at 30 kw could therefore be operated at 30, 25, 20, 15, 10, 5, or 2.5 kw with a fixed electron energy. In addition the electron energy can be varied by a factor of about 2, which changes the beam power. The electron energy is determined by the penetration required in the processing.

If high conveyor speeds were possible, the beam power would then be limited by exposure variation caused by too great a spacing between the electron pulses. The electron beam is roughly circular in cross section with the electrons concentrated near the center. With a distance from the accelerator window to the food package of about two feet, satisfactory exposure variation can be obtained if the electron bunches are spaced no more than two inches apart where they enter the surface of the food package. In one sweep of the beam across the 15-1/2 inch dimension of the V3 box there should be about 9 pulses. Scanning of the beam can be done in a manner which draws parallel lines across the package so that the exposure variation at the sides is the same as in the middle of the package. Assuming 9 pulses as the beam sweeps across the package and with a pulse repitition rate of 360 cps, the conveyor speed is 80 inches per second, or 400 feet per minute. Thus limitations on exposure variation limits the belt speed to about 400 feet per minute if the maximum pulse repetition rate is 360 cps.

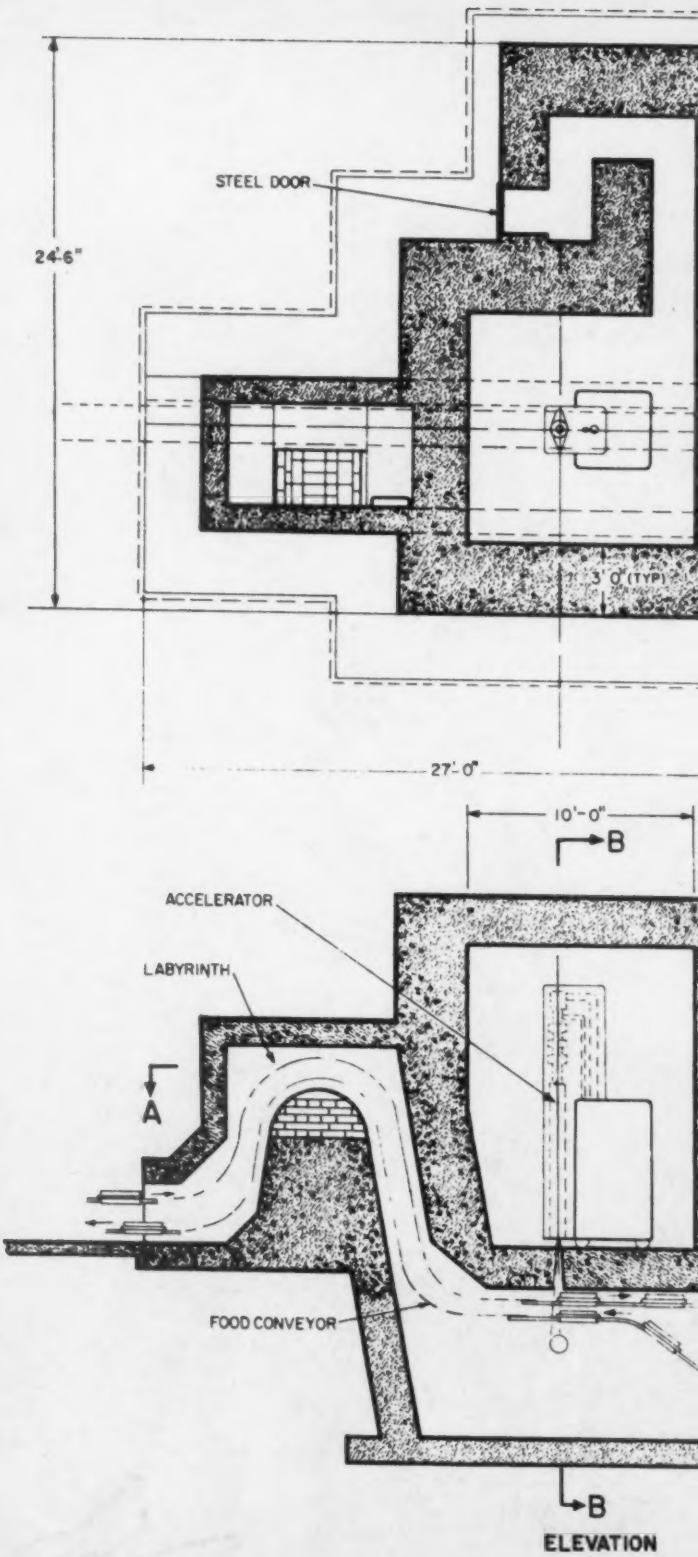
With the permissible 30 feet per minute speed of the conveyors presented in Fig. 6 and 7, satisfactory exposure variation can be obtained with a pulse repetition rate of only 27 cps. Since the minimum automatic pulse repetition rate with present linear accelerations is 30 cps, there is no problem of excessive exposure variation with the maximum conveyor speed of 30 feet per minute.

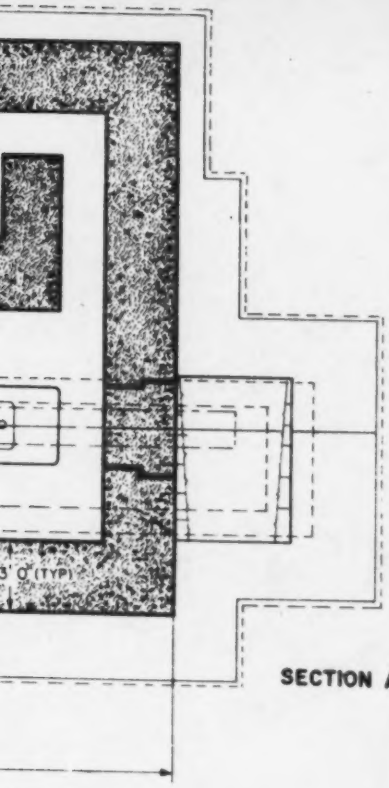
Since the electron-beam power is dependent upon the pulse repetition rate, it is not economic to attempt to use the same facility for processing of low-exposure foods such as potatoes and high-exposure foods such as sterilized meats. This can be demonstrated by considering the beam power requirements in the two cases. The beam utilization, or fraction of the electron energy which is usefully absorbed, is about 62 per cent after allowances for spill-over at the sides of the package, beam wastage between packages on the conveyor, X-ray production, and depth exposure variation.

For processing potatoes to 1.5×10^4 reps with a pulse repetition rate of 30 cps and a belt speed of 30 feet per minute, the required electron-beam power is 0.423 kw. Of this, 0.262 kw is absorbed in the potatoes. The through-put under this condition is 180 tons per 24 hour day; this figure assumes 34 pounds of potatoes per package of the dimensions of a V3 box. The same machine with the pulse repetition rate increased to 360 cps would have a beam power of 5.1 kw if the electron energy is the same. If used for processing meat at 50 pounds per package, the electron energy must be increased by 47 per cent because of the increased density, and the beam power would be 7.45 kw; of this, 4.62 kw could be usefully absorbed. In processing the meat to 2.5×10^6 reps, the output would be 19 tons per 24-hour day with a belt speed of 2.2 feet per minute. The conveyors presented are capable of speed variation by a factor of 10 from 3 to 30 feet per minute, although further speed reduction is possible by changing equipment in the primary drive units. Exposure variations from 1.5×10^4 to 2.5×10^6 reps are therefore practical with this arrangement. However, for the processing of high-exposure materials it would be economically advantageous to use a machine of higher power.

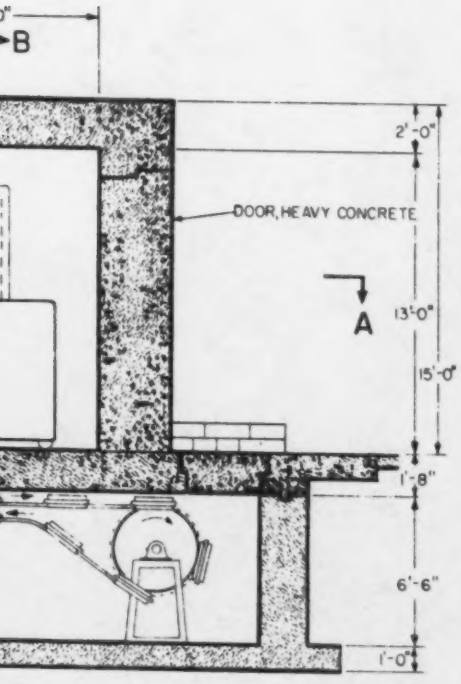
The problem of conveyor speed range arises because the machine power is variable by a factor of only 12, corresponding to changes in the pulse repetition rate from 30 to 360 cps, while the required exposure variation is from 1.5×10^4 to 2.5×10^6 reps, a factor of 167. A conveyor speed variation of 167/12, or about 14, is therefore required. This figure is independent of the density of materials processed; the maximum electron energy is used for the most dense material and reduced in proportion to density for lighter materials.

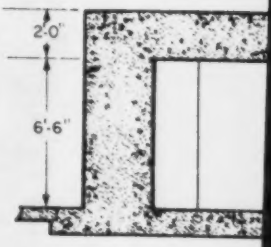
At the low pulse repetition rates and low beam power, the power input to the machine is reduced almost in proportion to the beam power but the capital costs on the machine become relatively more important; it appears probable that if accelerators are used in commercial plants, the plants will be designed for a narrow range of exposures. For purposes of cost estimating, two machine sizes are considered in the designs of the next section. One is the machine discussed above, with a maximum beam power of 7.5 kw, capable of processing potatoes at a rate of 180 tons per 24-hour day and with a capacity of 19 tons per 24-hour day of meat exposed to 2.5×10^6 rep. The minimum exposure which can be obtained at full power is 1.8×10^5 reps with the maximum conveyor speed


STEEL DOOR
24'-6"
3'-0" (TYP.)
27'-0"
10'-0"
B
ACCELERATOR
LABYRINTH
A
FOOD CONVEYOR
B
ELEVATION



SECTION AA

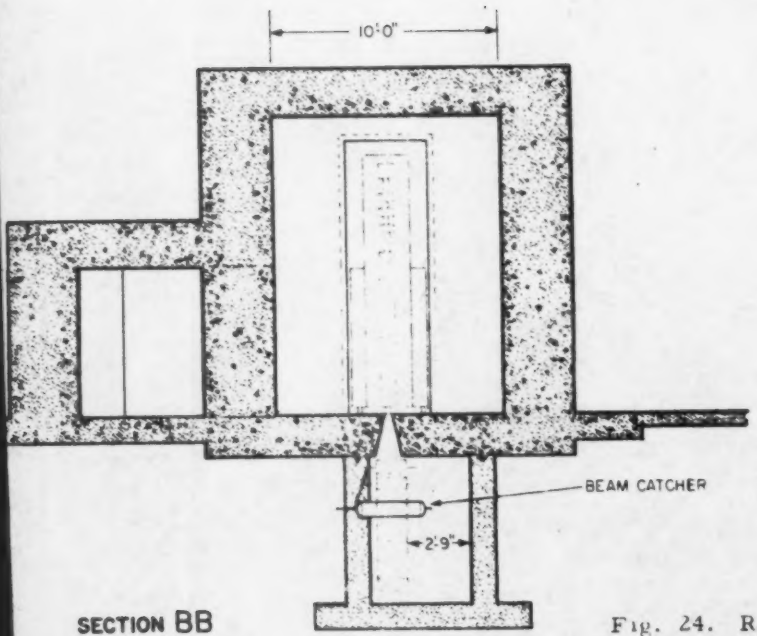




SECTION B

B

ATION



SECTION BB

Fig. 24. Radiation Cell for Single Accelerator

52249 O-60-pt. 1 (Face p. 549)

of 30 feet per minute. The second machine has a maximum beam power of 50 kw; the capacity for an item requiring an exposure of 2.5×10^6 rep is 128 tons per day with a conveyor speed of 14.4 feet per minute, if the density is 50 pounds per package.

The 50-kw machine cannot be used to process materials requiring less than 10^5 reps; this exposure is obtained at the minimum beam power of 4.16 kw with a pulse repetition rate of 30 cycles per second and a conveyor speed of 30 feet per minute. Attempts to obtain lower exposure with this machine by increasing the conveyor speed would result in exposure variations across the package produced by too large an interval between pulses. The processing rate with an exposure of 10^5 reps is 266 tons per 24-hour day. The minimum exposure obtainable at full power is 1.2×10^6 reps at the maximum conveyor speed of 30 feet per minute

B. DESIGN OF RADIATION FACILITIES FOR USE OF ACCELERATORS

Two designs are presented. In one, a single accelerator is used; this design is satisfactory for processing of dry materials. In the second design two accelerators are used to permit simultaneous exposure of opposite sides of a package, as would be required if the package contained a liquid. The cost of the machine increases less rapidly than does its beam power; it is therefore advantageous to use one large machine, for a given plant capacity, instead of two units of half power.

1. Radiation Cell and Conveyor Design - The radiation cell for the single machine is shown in Fig. 24. The waveguide is mounted vertically with the electron beam directed downward into the processing area. The machine is housed in a shield to protect operating personnel from the X-rays produced in the waveguide and is accessible by means of a walk-in labyrinth. For major repairs or replacement, the machine is removed through a large door in the shield.

Access to the radiation cell is by means of a ladder in the conveyor labyrinth. Large components of the conveyor enter the radiation cell through a removable plug in the top shield of the cell.

The conveyor passes through the electron beam twice. The packages are spaced on the conveyor so that the beam impinges upon first the upper package

52249 O - 60 - pt. 1 (Face p. 549)

then the lower package. The electron beam is scanned in a vertical plane normal to the direction of conveyor travel. The scanning angle is regulated to sweep across the width of the upper package then the lower package, the frequency of angle change being controlled by the conveyor speed.

A beam catcher, consisting of circulating water in an aluminum tube, is located under the conveyor to absorb the electrons which pass between packages and over the edges. Its purpose is to protect the concrete floor under the beam.

The conveyor is designed for the V3 box. The box is held in a frame by means of upper and lower clamps. During loading of the conveyor, a gate opens the top clamps to receive the box; for discharge the bottom clamps are parted, removing the box from the conveyor. During passage through the electron beam, the top clamps are parted to insure uniform exposure of the package.

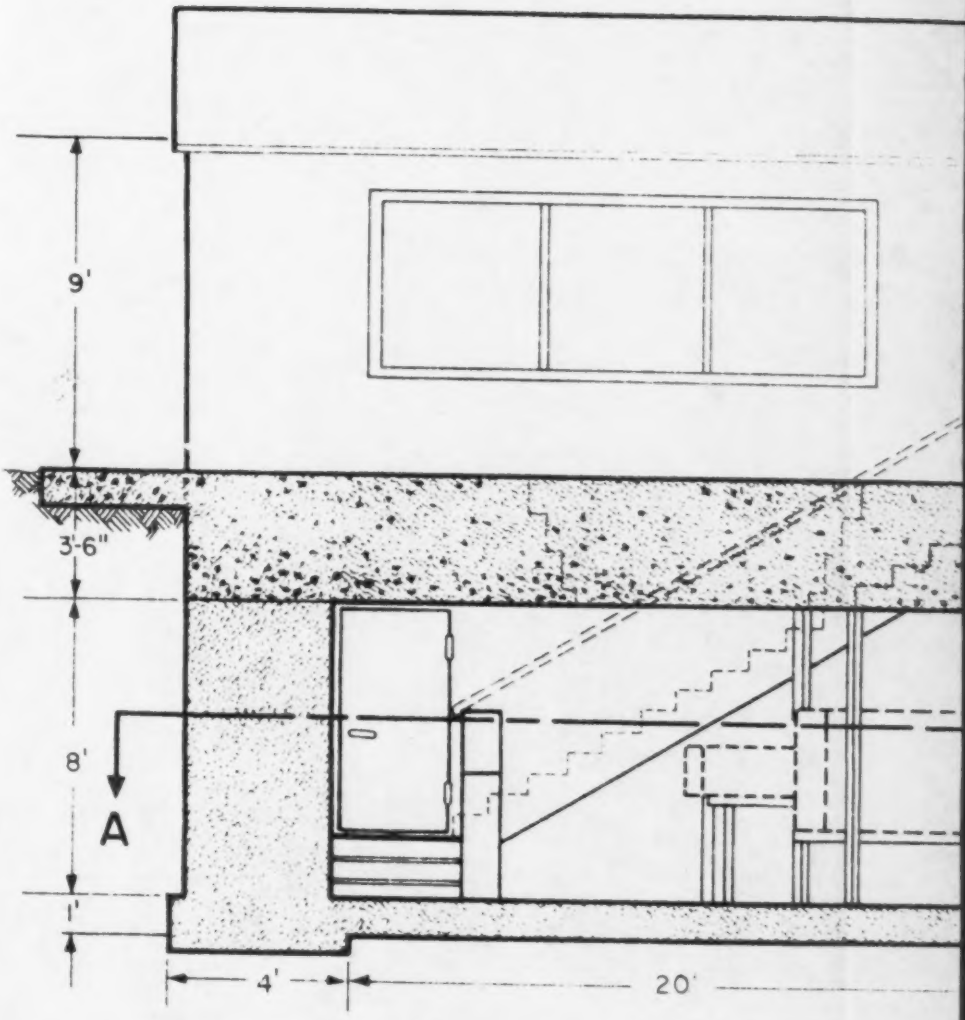
The radiation cell using two machines is shown in Fig. 25. In the plan view, the two machines are shown rotated from a normal to the conveyor; in this way no part of one machine is exposed to the beam from the other machine. The beam catchers indicated are aluminum tubes filled with water to protect the surrounding concrete when the beams fall between food packages. The beams are scanned in a vertical plane across the 15-1/2 inch dimension of the V3 box.

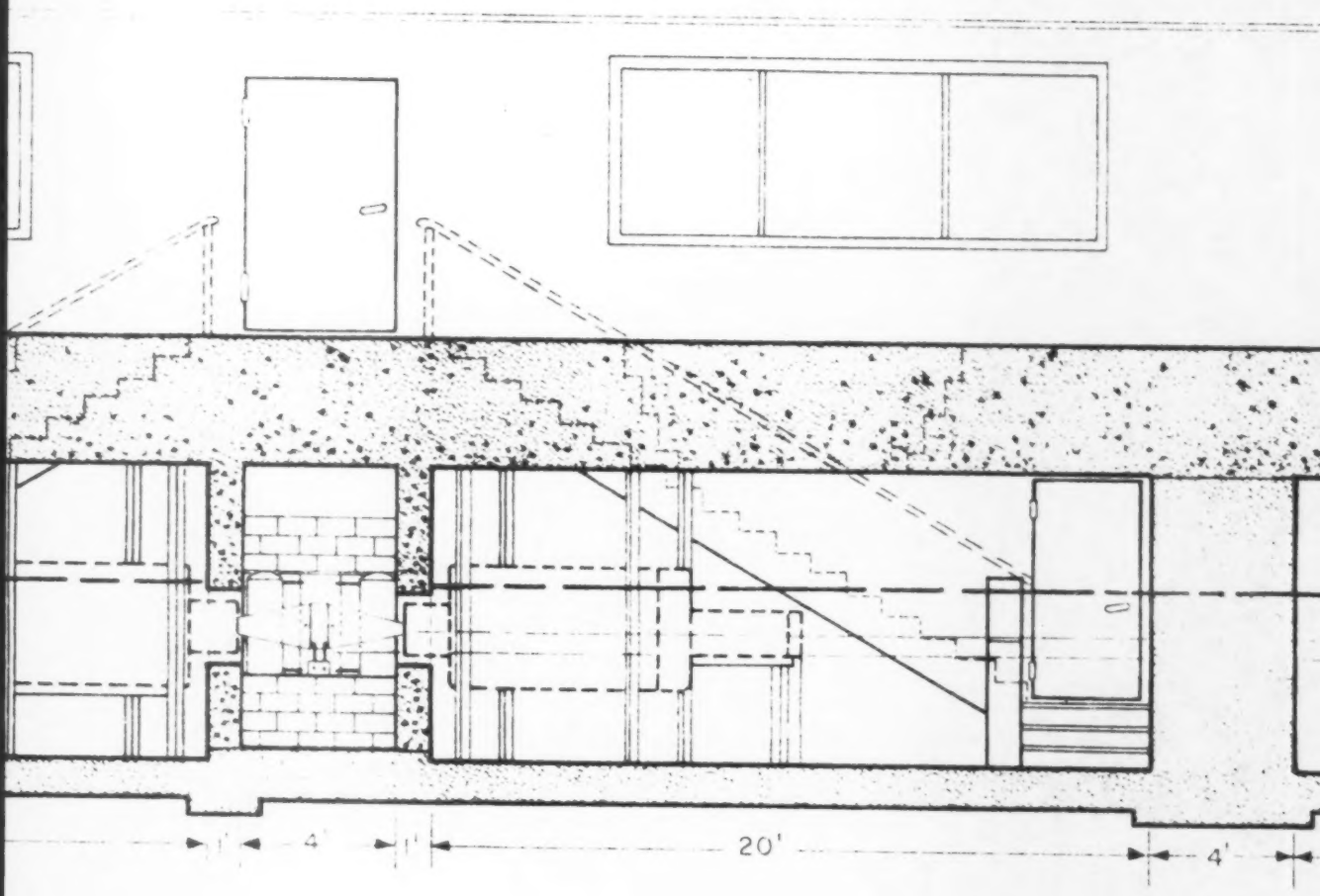
A two-conveyor system is used in this design. The exposure conveyor carrying the packages through the electron beams is a short loop confined to the radiation cell. All parts which are exposed to the electron beam are of aluminum to reduce the problem of induced activity from photon-neutron reactions. This conveyor arrangement is more conservative than that proposed for the single acceleration facility in that the conveyor which carries packages to and from the radiation cell is not exposed to the electron beam.

The exposure conveyor is loaded automatically from a feed and removal conveyor which makes a double loop around accelerator B. This conveyor operates in a horizontal plane and is loaded as indicated in Section C-C of Fig. 25.

The activity level in the radiation cell is expected to be sufficiently low to permit direct maintenance of the machines and food-handling equipment after shutdown. A shield plug is located over each machine to permit removal for major repairs or replacement.

52249 O - 60 - pt. 1 (Face p. 550) No. 1


9'
3'-6"
8'
A
1'
4'
20'


1'
4'
1'
20'
4'

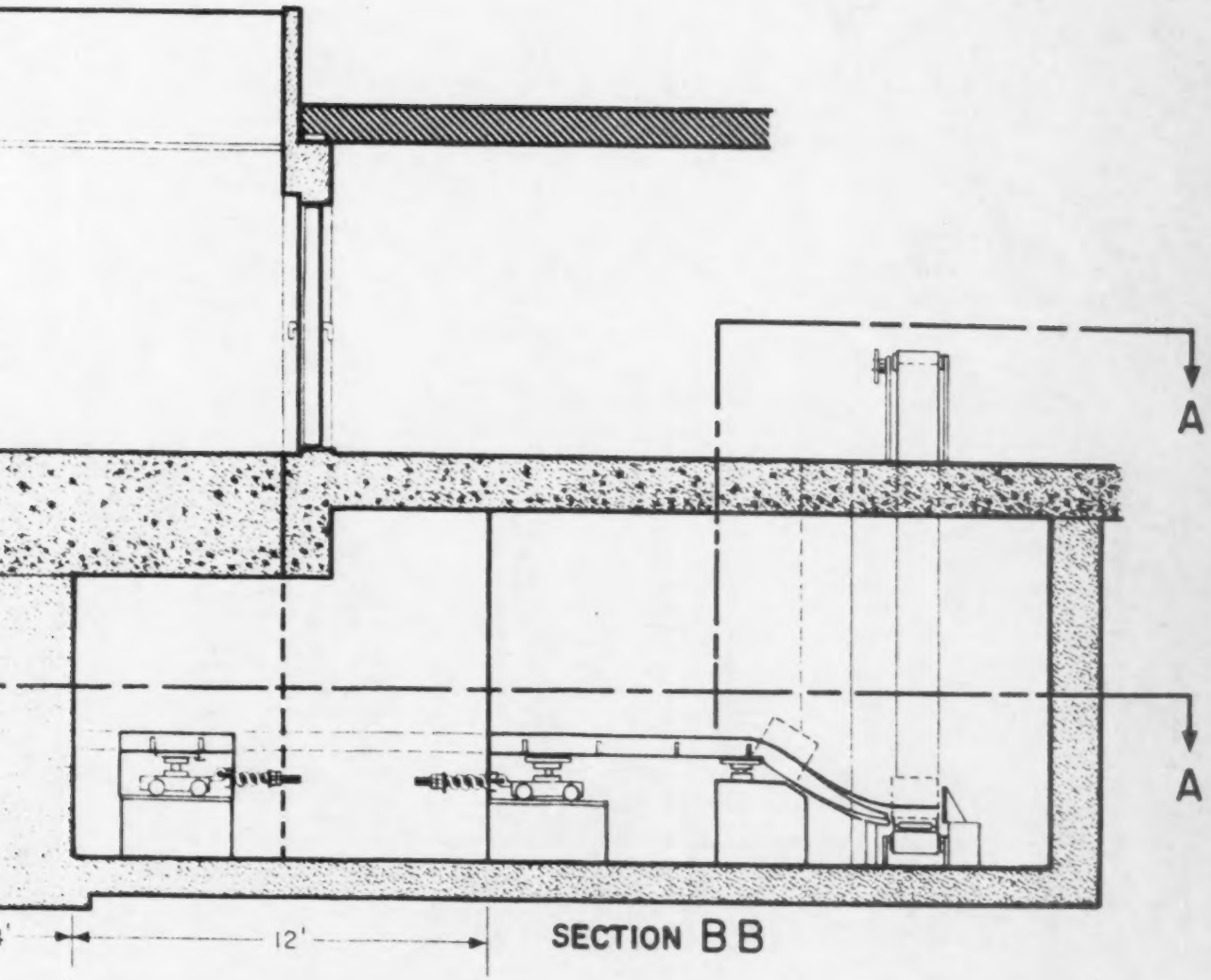
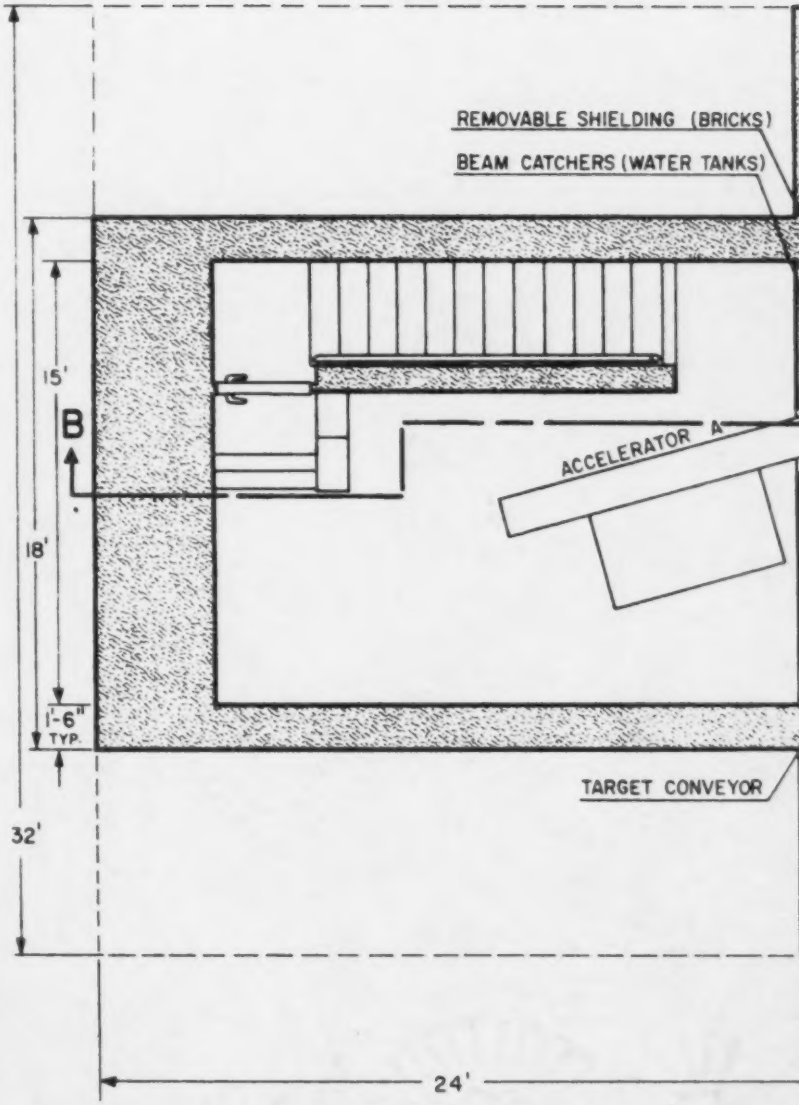
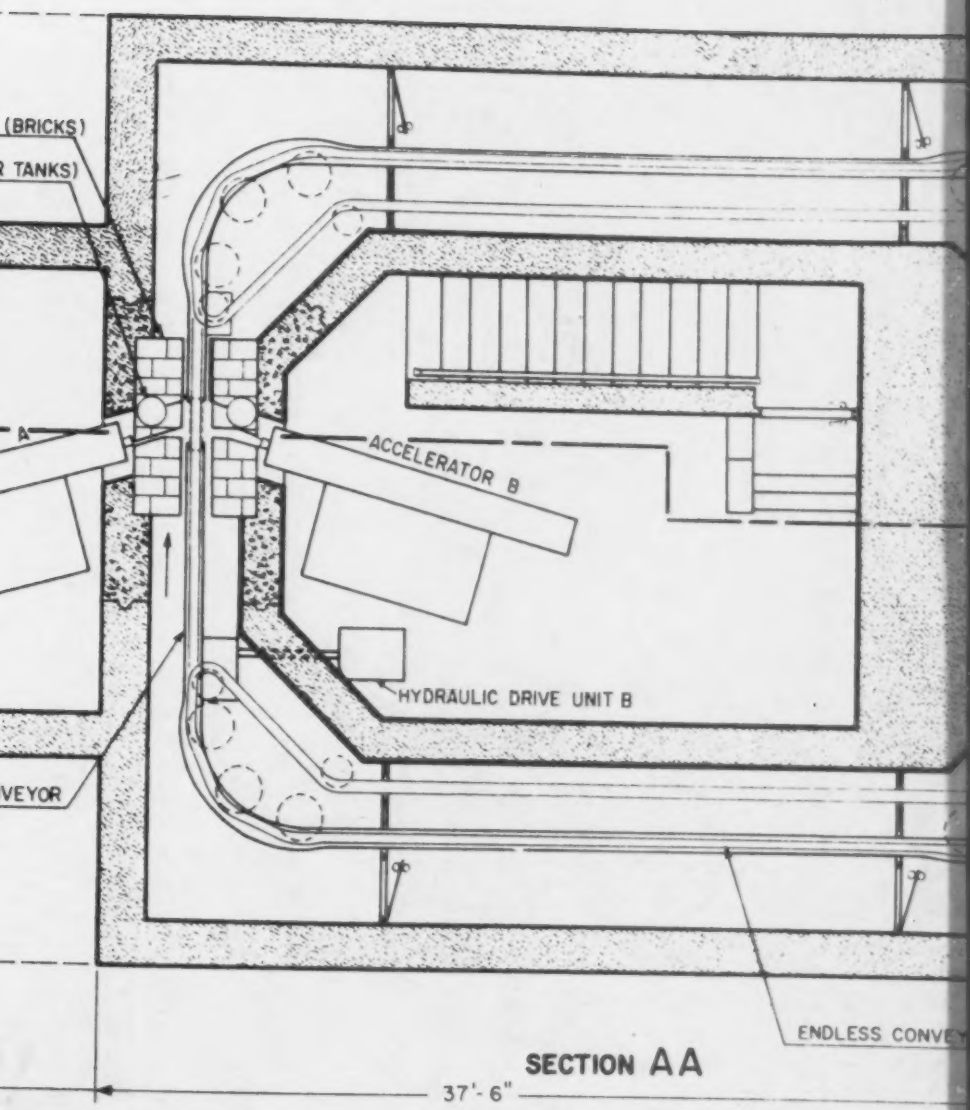


Fig. 25. Radiation Cell for Two Accelerators Part 1 of 4

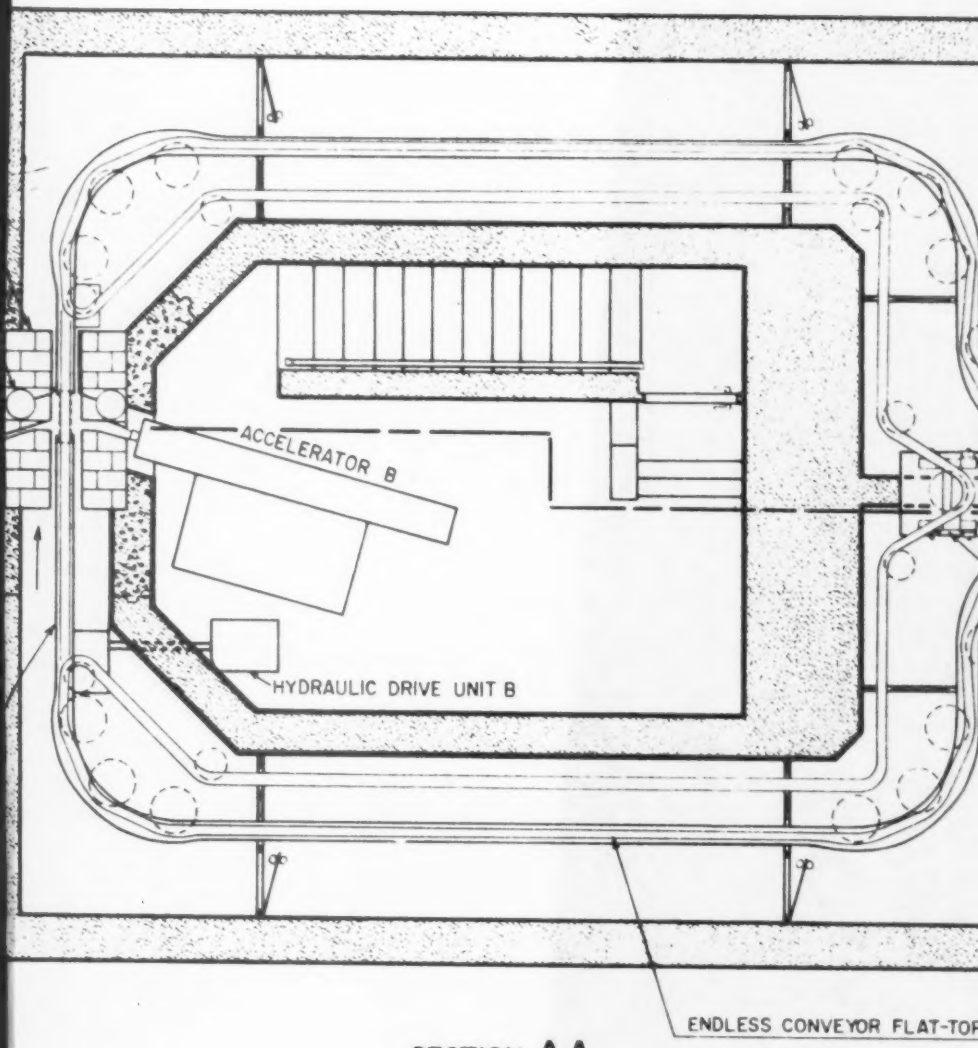


52249 O - 60 - pt. 1 (Face p. 550) No. 2



SECTION AA

37'-6"



SECTION AA

37'-6"

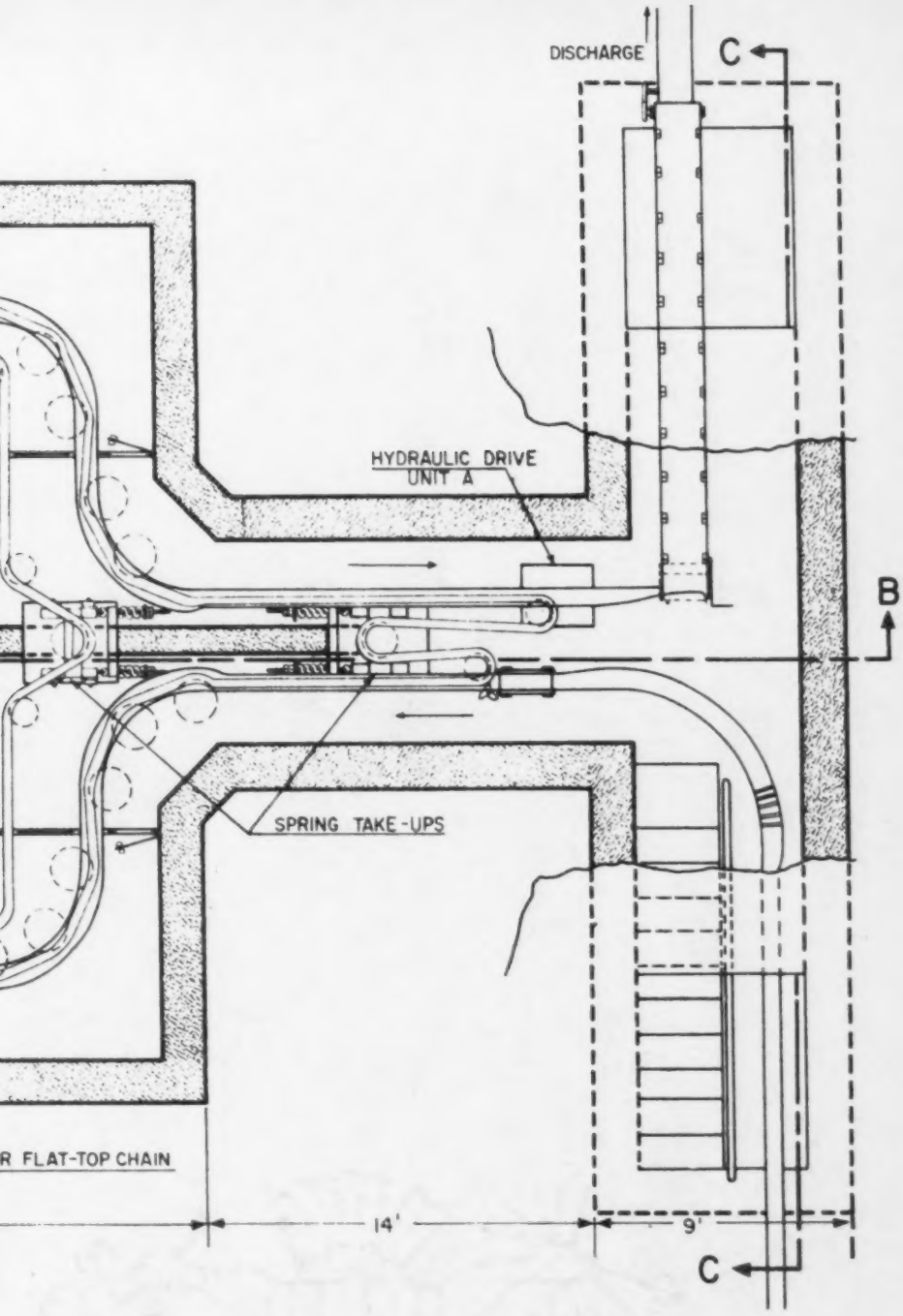
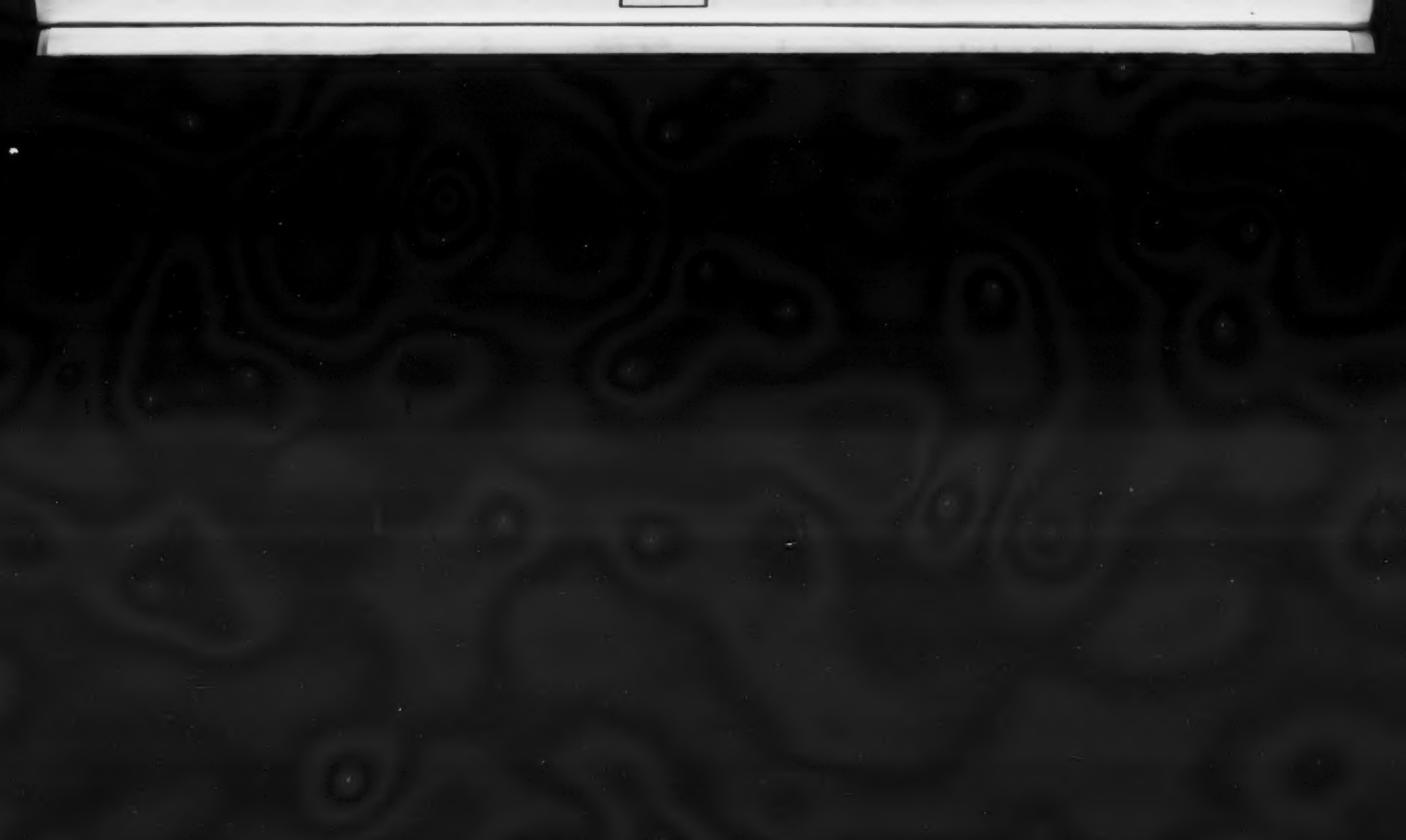


Fig. 25. Radiation Cell for Two Accelerators Part 2 of 4



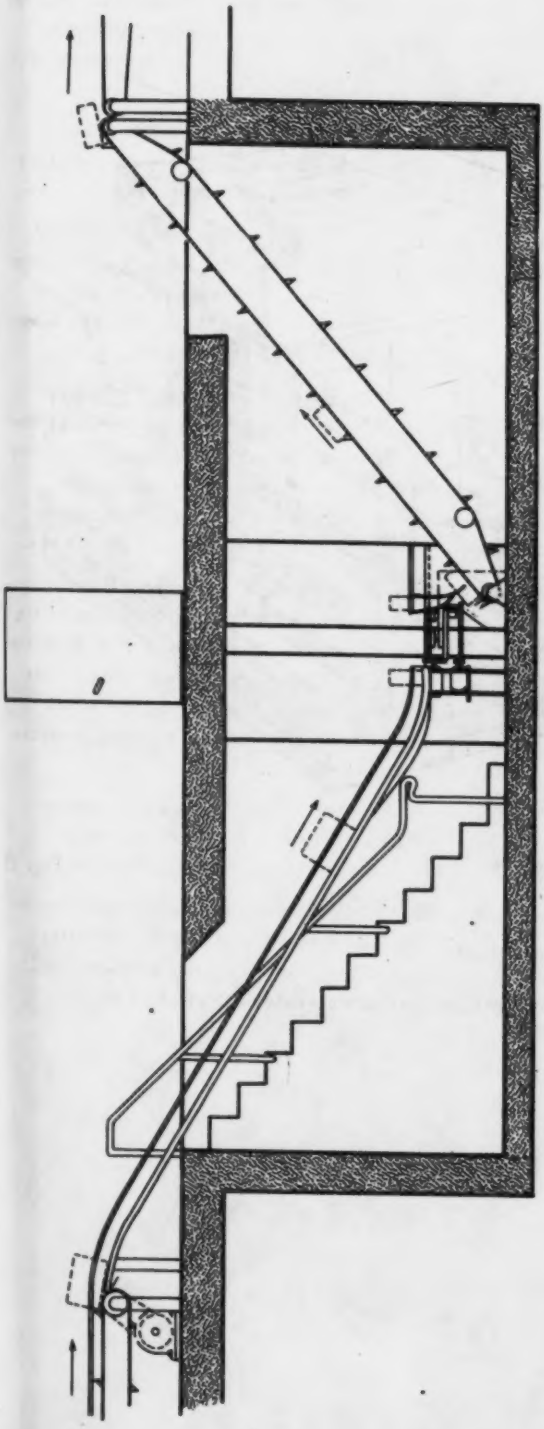


Fig. 25. Radiation Cell for Two Accelerators (Part 3 of 4)

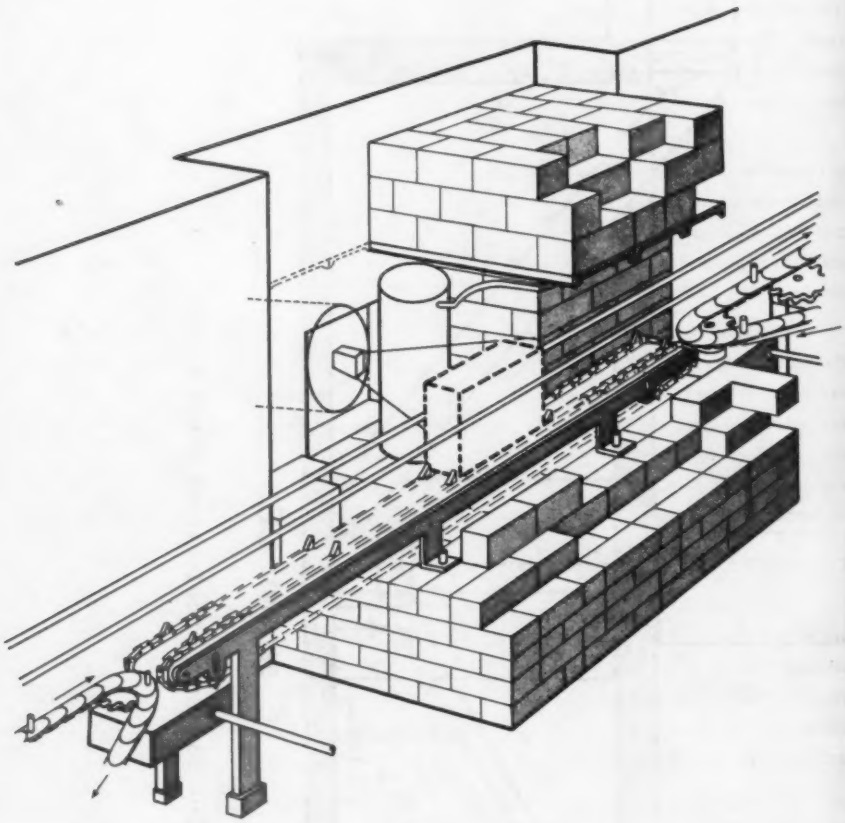


Fig. 25. Radiation Cell for Two Accelerators (Part 4 of 4)

2. Cooling and Containment - The main cooling load for the accelerator facilities is for the electrical and electronic equipment associated with the machine. The efficiency of a large machine, e.g., 50-kw electron beam, is about 12 per cent. The power input for such a machine is therefore 400 kw, of which 350 kw must be removed as heat. The linear accelerator has an internal cooling system; heat is exchanged to water which is cooled in a small cooling tower.

Four arrangements have been made of the electron processing facilities. In two of these the radiation cell design of Fig. 24 applies but machines of 7.5- and 50-kw beam power are considered. In the other two arrangements, the radiation cell of Fig. 25 applies and the two machines are 7.5- or 50-kw each. With the lower-power machine the efficiency is about 10 per cent and the cooling loads involved are 67.5, 135, 350 and 700 kw.

Cooling of the accelerator facilities is a simpler problem than cooling of the facilities using the various gamma sources because the problem of containing radioactivity is less troublesome. The estimates of induced radioactivity in the conveyors in Section VIII-A, 2 indicate the problem of containment is a minor one. In the conveyor design for the two-machine facility, the conveyor which is exposed to the electron beam is completely shielded and induced activity is important only during maintenance in the radiation cell.

C. PROCESSING CAPACITIES OF THE ACCELERATOR FACILITIES

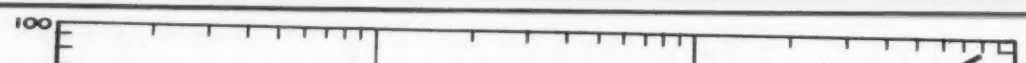
With machines of two sizes in each of the two radiation cells designed for use of the electron accelerator, there are four facilities. As discussed in Section VIII-A, 4 the processing capacity is a function of the exposure range required and of the density and dimensions of the material processed, since these determine the electron energy. Pertinent operating data for each of the four facilities are given in Table V.

The data of Table V were calculated assuming the material processed to 2.5×10^6 reps or to 10^5 reps has an average density of 50 pounds per cubic foot, and applies to meat packed in V3 boxes; the required electron energy is about 15 Mev. The figures for 1.5×10^4 reps applies to potatoes with an average density of 34 pounds per cubic foot; in V3 boxes, the required electron energy is about 10 Mev.

TABLE V

OPERATING DATA FOR THE ELECTRON ACCELERATOR FACILITIES

	Exposure (Reps)	Relative Electron Energy	Beam Power (kw)	Capacity (tons/24-hr day)	Conveyor Speed (feet/min)
Single Accelerators	2.5×10^6	1.0	7.5	19	2.2
(7.5 kw)	1.5×10^4	0.68	0.42	180	30
Single Accelerators	2.5×10^6	1.0	50	128	14.5
(50 kw)	1.0×10^5	1.0	4.2	266	30
Two Accelerators	2.5×10^6	1.0	7.5 (each)	38	2.2
(7.5 kw)	1.5×10^4	0.68	0.42 (each)	360	30
Two Accelerators	2.5×10^6	1.0	50 (each)	255	14.5
(50 kw)	1.0×10^5	1.0	4.2 (each)	530	30



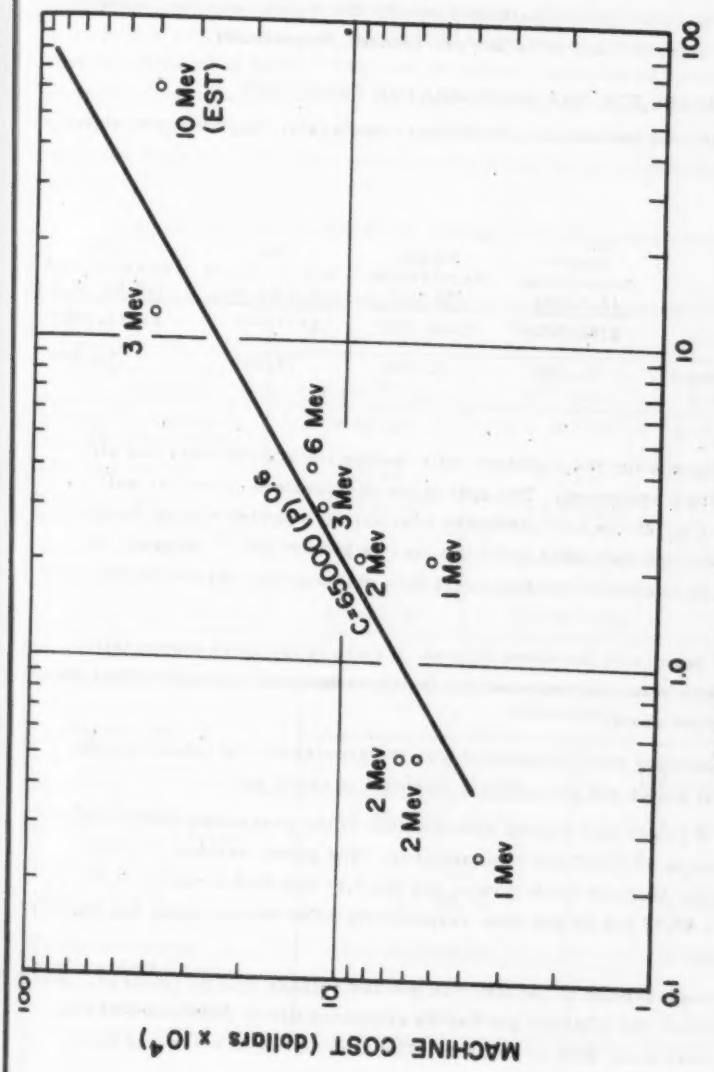


Fig. 26. Cost of Electron Accelerators vs Beam Power

The electron-beam pulse repetition rates for the highest and lowest beam powers in Table V are 360 and 30 cycles per second, respectively.

D. COST ESTIMATES FOR THE ACCELERATOR FACILITIES

The capital cost estimates for the four accelerator facilities are listed below:

	Single Accelerator (7.5 kw)	Single Accelerator (50 kw)	Two Accelerators (7.5 kw ea.)	Two Accelerators (50 kw ea.)
Radiation Cell	$382,000	$944,000	$717,000	$1,846,000
Conveyor Equipment	56,000	56,000	74,000	74,000

The cost figures for the radiation cells include the accelerators and all necessary operating equipment. The cost of the accelerators is not yet well established. In Fig. 26 the best estimates available are plotted against beam power. A line through the points gives the cost as $\$65{,}000\ (P)^{0.6}$ where P is the beam power in kilowatts; machine costs thus obtained are included in the above figures.

As can be seen from the above figures, the use of the more conservative two-conveyor system for the two-machine facilities does not markedly effect the over-all investment costs.

Special operating costs associated with the accelerator facilities are the cost of electrical power and periodic replacement of small parts.

The cost of power will depend upon location of the processing plant, but a reasonable figure is 10 mills per kilowatt-hour. The power demand is nearly proportional to the electron-beam power; for the 7.5- and 50-kw machines the power costs are $0.75 and $4 per hour respectively when the machines are operating at full power.

Periodic replacement of the electron gun and cathode will be required. For the 7.5-kw machine, the electron gun has an estimated life of 2000 hours at full power and will cost about $800 to replace. The cathode life is estimated to be

1000 hours; cost of replacement will be minor. For the 50-kw machine the estimated life of the electron gun is 1500 hours at full power; the replacement cost is estimated at $4000. The cost of cathode replacement is minor. The parts replacement costs for the 7.5- and 50-kw machines are therefore $0.40 and $2.67 per hour respectively when the machines are operating at full power. The costs per hour at lower power levels are assumed to be proportional to the beam power.

Using the figures thus obtained, partial unit processing costs are as follows:

Facility No. 1 (Single 7.5 kw accelerator)	Exposure		
	2.5×10^6 reps	10^5 reps	1.5×10^4 reps
Annual Through-put (at 90% Plant Factor)	1.25×10^7 lbs/yr	9.28×10^7 lbs/yr	1.18×10^8 lbs/yr
Machine Power	7.5 kw	4.1 kw	0.62 kw
Capital Costs (at 15% per year)	0.525¢/lb	0.0708¢/lb	0.0555¢/lb
Power and Parts Replacement Costs	0.073¢/lb	0.0082¢/lb	0.0013¢/lb
Partial Totals	0.598¢/lb	0.0790¢/lb	0.0568¢/lb

Facility No. 2 (Single 50-kw accelerator)	Exposure	
	2.5×10^6 reps	10^5 reps (Min)
Annual Through-put (at 90% Plant Factor)	8.40×10^7 lbs/yr	1.75×10^8 lbs/yr
Machine Power	50 kw	4.2 kw
Capital Costs (at 15% per year)	0.179¢/lb	0.0869¢/lb
Power and Parts Replacement Costs	0.063¢/lb	0.0025¢/lb
Partial Totals	0.242¢/lb	0.0885¢/lb

Facility No. 3 (Two 7.5-kw accelerators)	Exposure		
	2.5×10^6 reps	10^5 reps	1.5×10^4 reps
Annual Through-put (at 90% Plant Factor)	2.50×10^7 lbs/yr	1.86×10^8 lbs/yr	2.36×10^8 lbs/hr
Machine Power	7.5 kw (each)	4.1 kw (each)	0.62 kw (each)
Capital Costs (at 15% per year)	0.475¢/lb	0.0640¢/lb	0.0501¢/lb
Power and Parts Replacement Costs	0.073¢/lb	0.0082¢/lb	0.0013¢/lb
Partial Totals	0.548¢/lb	0.0722¢/lb	0.0514¢/lb

Facility No. 4 (Two 50-kw accelerators)	Exposure	
	2.5×10^6 reps	10^5 reps
Annual Through-put (at 90% Plant Factor)	1.68×10^8 lbs/yr	3.50×10^8 lbs/yr
Machine Power	50 kw (each)	4.2 kw (each)
Capital Costs (at 15% per year)	0.172¢/lb	0.0829¢/lb
Power and Parts Replacement Costs	0.063¢/lb	0.0025¢/lb
Partial Totals	0.235¢/lb	0.0854¢/lb

The above figures assume a constant density of process material so that the electron energy is fixed. The costs are compared with those of the other radiation sources in Section IX.

IX. USE OF X-RAYS FOR RADIATION PROCESSING

X-rays are an additional high-capacity source which may be used for irradiation-processing of foods. The penetration characteristics of X-rays are, of course, identical to those of gamma rays of the same energy since both consist

of electromagnetic radiation. Gamma rays and X-rays are differentiated on the basis of their origins, the X-ray being produced by the rapid acceleration of an electron while the gamma ray is emitted from a nucleus.

X-rays have the advantage of being presently available; none of the large gamma sources considered in this study are presently available except the neutron-activated indium (discussed in Section VII) which could be made available relatively soon by construction of a nuclear reactor.

X-rays were eliminated early in the survey of radiation sources on the basis of comparisons with the electron accelerator. The X-rays can be used in two ways: (1) low-energy, commercially available X-ray tubes could be used for surface irradiation of such materials as potatoes, to prevent sprouting, or fruits to prevent or delay the formation of mold; or (2) relatively high-energy X-rays, in the Mev range, could be used for processing in depth. Some form of electron accelerator is required for the production of high-energy X-rays.

All of the preceding material on radiation processing with gamma rays and high-energy accelerators has been concerned with processing in depth. The accelerator could be used for surface processing by reducing the electron energy to obtain the desired depth of penetration. The gamma-ray sources produce radiation which is highly penetrating and unsuitable for surface processing of any material for which processing in depth is undesirable. Comparisons are therefore made between X-ray machines and the electron accelerator.

A. COMPARISON OF X-RAYS AND ELECTRONS FOR SURFACE PROCESSING

To compare X-rays and electrons for surface processing, cost estimates were made for the processing of potatoes to prevent sprouting. The following operating conditions were assumed:

Capacity - 260 bushels/hr, 16 hours/day, 6 days/week, 26 weeks/year
Average potato diameter - 3 inches; sphericity factor - 0.8, unit density
Exposure - 1.5×10^4 reps required to 0.1 inch
Forty per cent geometry on utilization of X-rays or electrons

For the accelerator, a beam energy of 0.4 kw is required. The power input to the machine is 4 kw and machine cost from Fig. 26 is $37,500.

The following partial costs were obtained for the accelerator:

Machine Investment (15%/yr)	0.87¢/bushel
Power Cost	0.01
Machine Maintenance	0.20
Partial Total	1.08¢/bushel

The machine cost is high because of the poor plant factor of about 29 per cent.

With 50-kev X-ray tubes, the X-ray power was optimistically estimated to be 0.54 kw. The required X-ray power must be expected to be higher than for the accelerator because of the wide range, from 0 to 50 kev, of the X-ray spectrum; the lower-energy rays are absorbed near the surface and the higher-energy X-rays penetrate several centimeters. The efficiency with which electron energy is converted to X-ray energy is about 0.4 per cent in the 50-kev tubes. The electron-beam power is therefore 135 kw. The power input to the X-ray tubes will be higher by a factor of approximately 10, so the required input is 1350 kw.

At 1¢/kwh, the cost of power alone for processing of potatoes with X-rays is 5¢/bu.

A similar estimate was made for the use of 150-kev X-rays for which the efficiency of conversion from electron-beam energy to X-ray energy is about three times as high or 1.2 per cent. The utilization of the X-rays is even poorer than for the 50-kev X-rays and the power cost estimate is 9¢/bu.

From these estimates it is clear that X-ray tubes are not competitive with the electron accelerator for surface irradiation.

B. COMPARISON OF X-RAYS AND ELECTRONS FOR DEPTH PROCESSING

In comparing high-energy X-ray machines with the electron accelerator, the efficiency with which X-rays can be produced is the prime factor. The two machines are electrically similar in that a beam of high-energy electrons is produced. With the accelerator the electrons are used directly for radiation processing. With an X-ray machine the electron beam impinges upon a target made of a material of high atomic number, such as gold or tungsten; the resulting X-rays are then used for radiation processing.

As can be seen in Fig. 23, the efficiency of converting electron-beam power to X-ray power is a function of the incident electron energy. By use of an electron

energy of 20 Mev, an efficiency of about 45 per cent can be realized. To produce the same X-ray beam power as the electron-beam power from an accelerator, the power input to the X-ray machine must therefore be about twice as great. There would be very little difference in the initial costs of the two machines or in maintenance charges.

If use is made of high electron energies to obtain good conversion efficiencies, the X-rays are highly penetrating and cannot be utilized for processing as efficiently as can the electron beam. For a given processing capacity, the power input to the machine is therefore further increased, perhaps by 50 per cent. The cost of power for processing with X-rays is therefore at least three times as great as for the accelerator. The cost of the radiation cell would also be higher because of added shielding.

The problem of induced activity is aggravated by the use of high-energy X-rays. In the activity estimates of Section VIII-A, 2 the fraction of the electron beam converted to X-rays was about 7 per cent. The activity produced in processing with X-rays would be about 14 times as great as for the accelerator.

The problem of activity can be avoided entirely by using X-rays below the photo - neutron threshold in deuterium; i.e., below 2.2 Mev. At this energy the conversion efficiency is only 6 or 7 per cent, and power costs would be about 15 times as high as those for the accelerator.

If the electron accelerator is feasible for processing of foods, it is clear that the X-ray machine is in a poor relative economic position. The activity estimates of Section VIII-A, 2 lead to considerable optimism concerning the feasibility of processing foods with high-energy electrons; on the basis of this conclusion, X-rays were eliminated from further consideration in the study.

X. COMPARISONS OF THE RADIATION SOURCES

With the performance figures and partial processing cost estimates obtained in the preceding sections it is possible to make some meaningful comparisons of the various sources of radiation.

A. COMPARISONS OF UNIT PROCESSING COSTS

Partial unit processing costs have been obtained for exposures of 2.5×10^6 reps, 10^5 reps, and the minimum exposure possible with the facility design presented. These costs are reproduced in Table VI. From the figures of Table VI the following conclusions may be drawn:

1. For high exposures, e.g. 2.5×10^6 reps, the large accelerator is the most economic source of radiation.
2. For low exposures, the gamma sources are less expensive than the accelerator.
3. The least expensive source of gamma radiation is the gaseous fission products from a fluid-fuel reactor.
4. The gaseous fission products in spent fuel elements are a relatively expensive source of gamma radiation.
5. Gamma radiation from indium, produced in a reactor designed especially for this purpose, will not compete favorably with large by-product gamma sources when these become available.
6. The price of cesium-137 at which this source would be competitive with others is extremely low.

The validity of these conclusions is subject to several reservations. First, the capital investment estimates are based on preliminary designs for which costs cannot be accurately determined. The number of significiant figures in Table VI does not reflect the accuracy with which these costs are known. It must also be remembered that the designs of the radiation facilities presented have not been considered in sufficient detail for optimization, and that some sources may be presented in a relatively poor light. For example, the conservatism with which the containment problem for the gamma sources has been handled may favor the accelerator facilities for which the problem of induced activity has been minimized.

A third factor to be borne in mind is that many extrapolations had to be made in the study concerning costs. While there has been considerable experience in the handling of large quantities of radioactive materials in the operation of reactors, there is no comparable experience with electron accelerators of high power; questions of down-time and maintenance costs can be answered only by

TABLE VI

PROCESSING COST ESTIMATES

	Exposure		
	2.5×10^6 Reps	10^5 Reps	Minimum Exposure
Fuel Element Facility			(1.5×10^4 reps)
Capital Costs	2.05¢/lb	0.0820¢/lb	0.0123¢/lb
Gaseous Fission Products Facility			(3.5×10^4 reps)
Capital Costs	0.290¢/lb	0.0116¢/lb	0.0041
Special Operating Costs	0.070¢/lb	0.0028¢/lb	0.0010
Total	0.360¢/lb	0.0144¢/lb	0.0051
Cesium-137 Facility			(1.6×10^4 reps)
Capital Costs*	0.379¢/lb	0.0152¢/lb	0.0024
Sodium-24 Facility			(1.5×10^4 reps)
Capital Costs	0.648¢/lb	0.0260¢/lb	0.0039¢/lb
Activated Indium Facility			(6.2×10^4 reps)
Capital Costs	0.874¢/lb	0.0349¢/lb	0.0216
Special Operating Costs	0.528¢/lb	0.0211¢/lb	0.0131
Total	1.402¢/lb	0.0560¢/lb	0.0347
Accelerator Facility No. 1 (Single - 7.5-kw machine)			(1.5×10^4 reps)
Capital Costs	0.525¢/lb	0.0708¢/lb	0.0555¢/lb
Special Operating Costs	0.073¢/lb	0.0082¢/lb	0.0013¢/lb
Total	0.598¢/lb	0.0790¢/lb	0.0568¢/lb
Accelerator Facility No. 2 (Single 50-kw machine)			(10^5 reps)
Capital Costs	0.179¢/lb	0.0860¢/lb	-
Special Operating Costs	0.063¢/lb	0.0025¢/lb	-
Total	0.242¢/lb	0.0885¢/lb	-
Accelerator Facility No. 3 (Two 7.5-kw machine)			(1.5×10^4 reps)
Capital Costs	0.475¢/lb	0.0640¢/lb	0.0501¢/lb
Special Operating Costs	0.073¢/lb	0.0082¢/lb	0.0013¢/lb
Total	0.548¢/lb	0.0722¢/lb	0.0514¢/lb
Accelerator Facility No. 4 (Two 50-kw machine)			(10^5 reps)
Capital Costs	0.172¢/lb	0.0829¢/lb	-
Special Operating Costs	0.063¢/lb	0.0025¢/lb	-
Total	0.235¢/lb	0.0854¢/lb	-

*Does not include the cost of the cesium source.

operating such a machine. The costs of Table VI assume 90 per cent of continuous operation can be achieved.

Conclusion 1 is subject to uncertainties concerning the initial cost of the large accelerator, and the outage and repair costs. In addition there is the question of induced radioactivity, particularly in the conveyor, which may upon presentation of experimental evidence add appreciably to the cost of maintenance.

Conclusion 2 is partially the result of choosing accelerator facilities capable of exposing foods to 2.5×10^6 reps. If designed for an exposure of 10^5 reps, the machine power required is 2.8 kw, assuming the maximum conveyor speed of 30 feet per minute. With two machines of this power in the radiation cell design of Fig. 26, the cost of processing is 0.044 cents per pound for irradiation to 10^5 reps This is a considerable reduction from the figures of Table IV for the accelerator facilities. However, the cost is higher than for the more economic of the gamma sources and conclusion 2 is valid.

Conclusion 3 is subject to reservations concerning performance. As discussed in Section IV-D there is considerable doubt as to the gamma power which would be available from the fission gases in the design presented. Also, there is concern that the gamma energy spectrum from this source is not appropriate for processing foods if there are narrow tolerances on exposure. Analysis of the absorption characteristics of the gammas, as presented in Fig. 14, indicates the gammas are predominantly of low energy. If experimental evidence (more appropriate for the open gas system such as the one presented) proves this to be the case, overexposure of the surfaces of the food package would result. Even if the overexposure is not harmful to the food product the utilization of the gamma energy is impaired. It was assumed that 25 per cent of the gamma energy emitted by the radiators could be usefully absorbed in producing the minimum required exposure. This minimum would be produced at the center of a uniformly dense package, and overexposure of the surfaces is wasteful of gamma energy. It is therefore possible that the assumption of 25 per cent utilization for all the gamma sources favors the gaseous fission products to some extent. This assumption also probably penalizes sodium-24 since the high-energy gammas from sodium would give minimum exposure variation.

Conclusion 4 is partially the result of choice of fuel element. The choice of a fuel element from a power reactor was made on the basis of long, continuous

exposure in the reactor. The economics of power reactors are such that the fuel element should be of minimum enrichment in U-235. The remainder is primarily U-238, which is a good absorber of gamma rays. As a result, only 20 per cent of the gamma power of the fuel element escapes the element. While this is advantageous in that it eliminates most of the low-energy gammas, it results in a relatively weak radiation field in the processing chamber. It is possible that the fuel elements from high-enriched reactors such as the MTR could be used to better advantage for processing despite the rapid variation in activity with time with such elements and the limited processing capacity which could be supported.

With regard to conclusion 5, it should be stated that the special reactor built for production of gamma rays has an advantage over the byproduct gamma sources. This is the fact that it can be located wherever desired. This should result in lower shipping costs on the food product. Some important costs have been neglected for this gamma source, particularly the cost of reactor operating personnel. However, it is probable that careful design could lead to improvements in performance in terms of gamma power available per unit of reactor power; such improvements would reduce the cost of processing.

Conclusion 6 is somewhat surprising in that the radiation cell design is perhaps the simplest of those for the gamma sources. There is no price at which cesium could compete with the gaseous fission products if the latter performs as assumed. The price at which cesium could compete with sodium is 3.7 cents per curie; this figure assumes 12 per cent per year against the investment in the source and includes a makeup rate of 2.3 per cent of the source per year. It is improbable that separated cesium will ever be available at this low price.

The conclusions above also depend to some extent upon the plant size selected. In the designs of the fuel element and sodium-24 facilities, in which there are four radiation plaques, increasing the number of plaques would produce only small reductions in processing costs. Increasing the size of the radiation cell for the activated indium sulfate would produce a somewhat larger reduction in processing costs. An appreciable reduction in costs could be expected by increasing the number of radiation plaques in the facilities designed for use of gaseous fission products and cesium-137. The effects of plant capacity on the accelerator facilities are evident from the figures of Table VI.

While it was not possible under the scope of the study to consider the effects of variations in plant size for each of the radiation sources, it is believed that the relative economic positions of the several sources would not be changed appreciably as a result of size considerations.

B. COMPARISONS OF PROCESSING TIME

A figure of interest in addition to the cost of processing is the dwell time or time required for a food package to pass through the radiation cell. The time required for each of the radiation sources appears in Table VII.

TABLE VII

TIME REQUIRED FOR RADIATION PROCESSING

	2.5×10^6 Reps	10^5 Reps
Fuel Element Facility	4.4 days	4.2 hours
Gaseous Fission Products Facility	8.0 hours	19.2 min.
Cesium-137 Facility	11.7 hours	28.2 min.
Sodium-24 Facility	28.6 hours	68.6 min.
Activated Indium Facility	3.8 hours	9.2 min.
Accelerator Facility No. 1 (Single 7.5-kw machine)	42 min.	3.1 min.
Accelerator Facility No. 2 (Single 50-kw machine)	6.4 min.	3.1 min.
Accelerator Facility No. 3 (Two 7.5 kw machines)	50 min.	3.7 min.
Accelerator Facility No. 4 (Two 50-kw machines)	7.6 min.	3.7 min.

As is evident from Table VII, the dwell time for the accelerator facilities is considerably shorter than for the gamma facilities. This is because of the high-energy density of the electron beam with which millions of reps per minute is possible. The dwell time required to irradiate food to 2.5×10^6 reps in some of the gamma facilities is inconveniently long. With lower exposures, for which

the gamma sources have an economic advantage, the processing time is not unreasonable.

C. LIMITS ON EXPOSURE

As noted in Table VI, the entire range of exposures considered in this study (1.5×10^4 reps to 2.5×10^6 reps) is not obtainable in all of the radiation facility designs. This must not be construed to mean that it is impossible to design radiation facilities, with the radiation sources considered, to cover this range of exposure.

Higher exposure can be obtained in any of the radiation chambers by reducing the conveyor speed or by making more than one pass through the chamber. Lower exposures are obtainable by increasing the conveyor speed above the maximum capability of the designs presented (30 feet per minute) or by reducing the intensity of the radiation field.

With the accelerator this can be accomplished by using a machine of lower electron-beam power, although as concluded above, the accelerator becomes uneconomic at low power and low exposure. With the gamma sources the intensity of the radiation field can be reduced by spreading the gamma source over a larger area.

D. AVAILABILITY OF THE RADIATION SOURCES

Of the six radiation sources considered in this study, three can be made available relatively soon. These are the spent fuel elements, the accelerator and the reactor-activated gamma emitter. Fuel elements are presently available on a limited but expanding scale from research reactors. The first large power reactor in the United States will start discharging spent fuel elements in perhaps two years. While both the accelerator and the special reactor for gamma production require some development, they could be made available in about two years.

Next in line of availability on a large scale is probably sodium-24. It is expected that at least one large-scale sodium-cooled reactor will be in operation by 1960. Fluid-fuel reactors of high power from which gaseous fission products could be obtained appear to be somewhat further in the future. Cesium-137 will soon be produced at a rate of about 200,000 curies per year. Production of the quantity required for a processing facility of commercial size is many years away; the source in the facility presented is of 7.8×10^6 curies.

E. CONCLUSIONS

Assuming that radiation processing of foods is a practical process with respect to acceptability from the standpoint of flavor changes or other alterations, a subject with which this study has not been concerned, it seems reasonable to expect that the process will be used to a considerable extent in the food industry. In processing plants of large capacity with processes requiring high radiation exposure it is likely that electron accelerators will be used as the source of radiation. For low capacity plants or processes requiring low exposure, gamma sources have an economic advantage and will be utilized.

REFERENCES

1. G. R. White, "X-Ray Attenuation Coefficients from 10 kev to 100 Mev," NBS 1003, May, 1952.
2. H. Goldstein and J. E. Wilkens, Jr., "Calculation of the Penetration of Gamma Rays," NYO 3075, June, 1954.
3. F. H. Clark, "Decay of Fission Product Gammas," NDA 27-39, December, 1954.
4. T. C. Engelder, "Heat Generation by Elements in the Fission Products," DOW-NR-54002-1, July 12, 1954.
5. R. L. Ashley, unpublished work at Atomics International.
6. K. Way and E. P. Wigner, Phys Rev. 70, 1946.
7. H. M. Busey, "Composition and Decontamination of Residual Water-Boiler Off-Gas," LA-1521, March, 1953.
8. "Reactor Design and Feasibility Problem - A Food Sterilization Reactor," Unclassified Report to be Published at ORNL.
9. AEC Sets U and D_2O Charges - News Item from Nucleonics, 13 No. 9, p. 110 (1955).
10. C. W. Miller, Paper No. 276 (Presented at the Industrial Electronics Convention, Oxford, 1954 - Published in British Institute of Radio Engineering).
11. Am. Scientist 40, p 404 (1952).
12. D. J. Hughes and J. A. Harvey, "Neutron Cross Sections," BNL 325 (U.S. Government Printing Office, Washington 25, D.C., 1955).
13. E. G. Fuller, Phys. Rev. 79, No. 2, p.303 (1952).
14. B. D. McDaniel, R. L. Walker, M. B. Stearns, Phys. Rev. 80, No. 5, p 807 (1950).
15. "Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water," National Bureau of Standards Handbook No. 52, 1953.
16. Personnel Communication from Col. George E. Danald, U.S. Army Quartermaster Corps.
17. N. V. Sidgwick, Chemical Elements and Their Compounds, Clarendon Press, Oxford (1950).

Appendix 4

EVALUATION OF SIZE OF USAIRC AND LOGISTICS OF IRRADIATED MEAT

Report to

QUARTERMASTER RADIATION PLANNING AGENCY, QUARTERMASTER R&D COMMAND

December 11, 1959

C-60431

I. SUMMARY

A. AUTHORIZATION

This study was authorized by the Quartermaster Radiation Planning Agency in a letter dated July 17, 1959.

B. PURPOSE

The general purpose of this study was to develop information useful as a partial basis for an evaluation of the USAIRC project relative to the Army's Research and Development program. The specific purpose was to answer two questions posed by Dr. R. S. Morse, Director of Research and Development, Department of the Army.

This report covers our study of the appropriateness of the size of the United States Army Ionizing Radiation Center as currently planned and our evaluation of the logistic consequences of radiated food for military purposes.

C. FINDINGS

Question 1. Is the food irradiation facility (USAIRC) as planned of the proper size to determine the engineering feasibility and practical economics of irradiated meats and to supply enough material for adequate field tests?

Answer

The facility is adequate in size and not too large for the objectives.

Comment

In our opinion, a facility embodying USAIRC concepts is necessary to ensuring the maintenance of representative industrial food-handling practices and conditions. No other currently available irradiation facility seems adequate in this regard.

If properly operated, the facility will demonstrate factors of engineering feasibility and will yield practical economic data useful in

the design of other cobalt 60 or LINAC facilities. It will not demonstrate feasibility or yield economic data concerning factors peculiar to other gamma sources or to other types of electron accelerators.

During the first years of operation, a great deal of experimental work will be necessary; production rates will average substantially less than the instantaneous design rate of 6000 megarad pounds per hour. On the basis of a 4.5-megarad dose, a 40-hour week, and the currently proposed range of container sizes, we estimate that the net annual combined output from both radiation sources available for test purposes will be equivalent to 1800 tons of meat.

Definitions of the scope of "adequate field tests" and the associated food requirements do not exist yet. Rough estimates, based on suggestions made by representatives of the Quartermaster Corps, indicate that engineering and user tests might require about 1400 tons per year. The requirements for adequate field tests need further definition.

Requirements for an adequate field-test program on meat alone will take up the radiation capacity of the facility on the 40-hour-per-week basis. This leaves a reasonable amount of capacity for experimental production of other radiated foods for testing. It appears that the facility is large enough for adequate testing on a reasonable scale, but is not significantly oversized for such purposes.

Our calculations indicate that at this late date, reduction in cost by reduction in scale would be small in comparison with the reduction in throughput capacity. After the experimental and demonstration periods were over, and if design production capacity were achieved, the facility could produce enough meat to supply about four divisions (15,000 men per division) with one pound of meat per man per day. This might turn out to be useful and significant in an emergency, since our study indicates that additional radiation facilities might take at least two years to activate.

Question 2. Is there a significant logistic advantage for irradiated meat in comparison with frozen meat, and if any, what is the order of magnitude?

Answer

In terms of dollars, men, and materiel, the logistic advantages of irradiated meat are essentially counterbalanced by disadvantages.

52249 O—60—pt. 1——37

Comment

The cube and weight of packaged irradiated meat are comparable to the cube and weight of frozen and canned meat.

Relative to frozen meat, the higher production and packaging costs for irradiated meat appear to outweigh the savings due to the elimination of refrigerated transport and storage.

When a linear accelerator is used, there is a slight saving for irradiated meats. In the case of a cobalt 60 source and irradiated enzyme deactivated meat, approximate breakeven points occur: (1) when irradiation costs are based upon manufacturing costs alone, and cobalt 60 costs are just under 50¢ per curie; (2) when irradiation costs are based upon manufacturing costs plus provision for a return on investment, and cobalt 60 costs are less than 28¢ per curie. For irradiated cooked meats, breakeven occurs at somewhat higher cobalt 60 costs.

On the basis of a Division Slice plus one Wing Slice (50,250 men), elimination of refrigeration would release 28 to 38 men for other duties and would save up to $119,000 in equipment investment. Effects of reduction in investment were included in the cost comparisons cited above.

Over-all Conclusion

In the light of current knowledge, there is no basis for choosing either frozen or irradiated meat to the exclusion of the other for military purposes; costs are about the same within the limits of accuracy of available data. The potential advantage of irradiated meats lies in the possibility of their making improved rations available to combat troops. In the case of irradiated meat, freedom from the need for refrigerated storage and transportation may have logistics implications in military planning, entirely apart from cost considerations; for example, less rigid scheduling, greater ability to alter plans on short notice, and greater flexibility in transportation may have a substantial significance that our study could not take into consideration within the time available.

To the extent that irradiated meats are proved to be an improved ration, our study indicates that radiation sterilization of meat may equal or excel refrigeration as a technique in military feeding systems. It seems reasonable for military planners to foster research and development work on this subject and to try to interest commercial producers. The costs and circumstances associated with the project are such that commercial interests are unlikely to go forward on their own, and government initiative and financial support are required.

If the Department of the Army has an over-all interest in the military significance of irradiated food, it would do well to examine the possible use of irradiated food as a source of stockpiled supply in the event of a Zone of the Interior disaster of considerable magnitude.

II. INTRODUCTION

A. PREVIOUS REPORTS

Our findings were reported orally to representatives of the Quartermaster Corps on September 1, 1959. A written summary of our findings was submitted to the Quartermaster Corps and Dr. R. S. Morse on September 2, 1959. This report is consistent with both our oral report and the written summary.

B. ASSUMPTIONS

Five simplifying assumptions were imposed upon our study:

1. Induced radioactivity in foods will not create a health hazard.

2. Only beef, pork, ham, and chicken will be considered in cost and logistic comparisons.

3. The "quality" of irradiated meats will be indistinguishable from that of refrigerated meats.

4. The location of the radiation facility at Stockton, California will not be questioned.

5. Both accelerator and gamma sources will be used for radiation; if radioactive cobalt is used, the price will be an assumed $1 to $2 per curie. (We estimate the price of commercial cobalt 60 at 50¢ to $1.)

C. METHOD

In conducting this study, we interviewed (1) personnel in the office of the Quartermaster General, the Quartermaster Food and Container Institute, Varian Associates, Curtiss-Wright Corporation, and the four companies comprising Irradiated Products, Inc.; (2) certain food-industry personnel; and (3) individuals formerly associated with the irradiated-food project. Logistic factors were discussed with a representative of the Command and General Staff College in Fort Leavenworth, Kansas.

We utilized certain reports and data that had been compiled for or by the QMC. In addition, various QMC representatives helped us gather together specifically requested pieces of information used in our study.

All persons interviewed gave their wholehearted cooperation; their assistance is gratefully acknowledged.

III. THE USAIRC AND FOOD IRRADIATION

The concept of the USAIRC took shape in 1955. Budget allocations were included in the plans for fiscal 1957. The supporting program was intensified so that certain problems might be solved before the scheduled operation of the USAIRC.

The principal purpose of the USAIRC was to gain processing experience and cost data by operating a large pilot plant that would furnish (1) material for large-scale handling and feeding tests and (2) irradiation services for both government agencies and industry. (A more detailed statement of objectives is contained in Appendix A.) The USAIRC was seen as facilitating the broadening of a program from one sponsored entirely by the military to one sponsored partly by industry and partly by government agencies.

Since 1955, universities and company laboratories have worked on the program. Foods have been irradiated in various facilities at Dugway, Savannah River, and Idaho Falls. Some animal and human feeding tests have been completed. The studies made at various laboratories have covered a wide range of topics.

At present it appears that most meats important for military purposes will require a 4.5-megarad dose for adequate sterilization. Enzyme deactivation prior to irradiation seems to be necessary. This requires some heat and results in a partially cooked rather than a raw product. Representatives of the Quartermaster Food and Container Institute feel that shrimp, halibut, and bacon, chicken, and pork products can be made quite acceptable. Irradiated beef has varying degrees of off-flavor. Some irradiated beef with little off-flavor has been produced. QM people are sanguine concerning eventual success in producing irradiated beef and other meats of acceptable quality. The properties of fruit and vegetables are significantly affected at sterilizing doses; substantial color and texture changes have been observed. It seems likely that many irradiated foods will differ considerably from their fresh counterparts. The effect of such changes upon acceptability has not been fully evaluated.

QM representatives believe that irradiated foods will be proved wholesome in all respects. The extent of induced radioactivity is under study by various QM contractors.

Food companies have greatly reduced their research activity in this field, partly because of the problem of off-flavors and odors from irradiated foods. Industry does not feel justified in undertaking so vast a project, and is in effect standing by until new information comes out of USAIRC. Some companies are interested in pasteurized or surface-irradiated foods. Commercial activity may begin in this area when the question of indirect radioactivity is resolved. The continuing program will have to be supported almost entirely by the government.

Continued laboratory-scale research will be required for some time after activation of the USAIRC. The facility is meant to ensure the simulated development and control of commercial food-processing conditions in a manner and on a scale adequate to yield engineering and cost data and other information not reliably attainable from laboratory work.

A design of the USAIRC building has been completed by the Corps of Engineers; an order has been placed with Varian Associates for a linear accelerator (LINAC), and the unit is partially built. Of the total budget of $1.6 million, $624,000 has been spent. The research and development phase of a broader contract with Curtiss-Wright for a cobalt 60 facility (HIFI) has been completed. Of the total budget of $2.2 million estimated for the HIFI, including housing, $361,000 has been spent.

Irradiated Products, Inc., has been formed by the joint efforts of four companies concerned with various aspects of food processing. This group has been primarily concerned with planning the operation of USAIRC.

IV. EVALUATION OF USAIRC SIZE

A. DESIGN CAPACITY

The size of the proposed irradiation facility was initially expressed for each of two radiation sources as 1000 tons per month of unit-density material irradiated with a 1-megarad dose. This production capacity also assumed the use of a 6" x 16" x 24" package and operation 24 hours per day, 28 days per month.

More recently, the capacity has been expressed as 6000 megarad pounds per hour from each of the two sources. This figure assumes the package noted above. Under the operating schedule noted above, this capacity at a dose of 2.0 megarads is equivalent to 1000 tons per month per source.

We found no authoritative documentation covering the derivation or selection of the planned design capacity. In our evaluation, we assumed that if the USAIRC were somewhat larger than necessary for obtaining engineering and cost data, we could compare its production capability with available estimates of the amount of material required for testing purposes. We could also estimate the savings that might be realized if a smaller facility were built, taking into account the time and money already spent. The possible savings could then be judged in the light of other pertinent factors.

B. ESTIMATED PRODUCTION

The production capacity stated above must be regarded as an ideal. Designating the instantaneous production rate, it is useful for deriving the size of equipment and the amount of space required.

The total production over a given period when the facility is operating at the instantaneous design rate is directly dependent upon such factors as:

1. The plant operating schedule, i.e., shifts per day, days per month.

2. The amount of time required for experimental purposes.

3. The types of packages (see Appendix B).

4. The irradiating dosage.

5. The frequency and duration of shutdowns due to equipment failures or required alterations.

6. The lost time due to difficulties in scheduling the arrival of material for processing.

7. Startup and shutdown time losses.

It is planned to operate the USAIRC initially on a 40-hour week. Meat will be given a 4.5-megarad dose. Assuming (1) a one-shift operation, staggered to assure the feeding of meat to the irradiating facilities for eight hours per day, (2) a 10% reduction of output due to experimental operations, (3) a 10% reduction of output due to shutdowns, and (4) use of the full range of packages, we estimate the approximate output from each facility to be 75 tons per month. Combined, this totals 150 tons per month, or 1800 tons per year. These estimates are detailed in Table I.

It seems reasonable to assume that as long as experimental programs are in progress, the output on a 40-hour-per-week basis will not greatly exceed those estimated above. The output can be expected to increase primarily if more hours are worked per week. The maximum output, assuming a 4.5-megarad dose, would be in the order of 7000 tons per year.

It should be noted that the LINAC design capacity is realized only at the beam energy for which it is designed. Below the design beam energy, the percentage of capacity reduction is proportional to the reduction of beam energy. Above the design beam energy, the capacity drops off sharply. Modifications can be made to permit the LINAC to maintain the production capacity constant as the beam energy is lowered. Since such modifications are not currently planned, the capacity of the LINAC when operating at other than 24 MEV will be below those estimated above.

TABLE I

PRODUCTION CAPACITY UNDER VARIOUS CONDITIONS
(Dosage: 4.5 Megarads)

	HIFI[1]		LINAC[2]	
	Standard Package (6" x 16" x 24")	#2-1/2 Can	Standard Package	#2-1/2 Can
Design capacity (lb/hr)[3] (i.e., 6000 megarad-lb/hr, 24 hr/day, 28 days/mo.)	1,350	816	1,350	653
Design capacity (tons/mo.)	450	272	450	218
Capacity @ 40 hr/wk (tons/mo.)	115	70	115	55
Capacity with 10% allowance for experimental work plus 10% for other shutdowns (tons/mo.)	92	55	92	43
Approximate average per facility (tons/mo.)	75		70	
Average for USAIRC (tons/mo.)	150			
Annual production (tons/yr)	1,800			

1. HIFI = High Intensity Food Irradiator, i.e., cobalt 60 source.
2. LINAC = Linear Accelerator.
3. Capacity figures represent net contents of packages.

Arthur D. Little, Inc.

C. TECHNICAL FEASIBILITY

1. Over-all Operation

In the opinion of the manufacturer, the size of the LINAC under construction for USAIRC represents the limit of current technology. The cobalt 60 facility as currently planned would be the largest gamma source ever used. For these reasons one can conclude intuitively that proper operation will contribute extensively to the accumulation of valuable information concerning the engineering feasibility of the two irradiating sources.

The food-preparation area is to be equipped with commercial-scale food-processing equipment and facilities that will permit accurate simulation control of processing conditions. Proper operation of the integrated plant under schedules representative of commercial practice should yield valuable information by which the engineering feasibility of the over-all operation can be judged.

At this time, it cannot be stated positively that the over-all operation will be technically feasible and that the mere operation of the USAIRC will demonstrate its feasibility on a substantial scale. Many processing methods must be studied both in the laboratory and at the USAIRC before the feasibility of the process is fully established.

In our judgment, the USAIRC will make possible a useful determination of the degree of engineering feasibility of the irradiation sterilization of meat by the LINAC and cobalt 60 sources.

2. HIFI

Information on the HIFI should be directly applicable with confidence to the design of larger cobalt 60 sources. Certain kinds of information about pre- and post-irradiation processing requirements, materials-handling concepts, instrumentation, shielding design, and availability or reliability of equipment other than the irradiating sources would be equally applicable to the design of plants involving other gamma sources. Other information obtained would contribute to the design of facilities using other gamma sources, but additional data would be required. Some of this data might be available outside the USAIRC; if not, it would have to be accumulated. The engineering feasibility would then have to be re-evaluated. For example, the accuracy of dosimetric design calculations could be established at the USAIRC for cobalt 60 sources. It could not, however, be established

1. HIFI = High Intensity Food Irradiator.
2. LINAC = Linear Accelerator.
3. Capacity figures represent net contents of packages.

for cesium 137 sources. The additional data necessary might become available from Brookhaven National Laboratories, where work is being done on this nuclide. Data for other gamma sources would probably require experimental work.

The operation of USAIRC would contribute little to the technology of irradiating food with other gamma sources. Their efficiency and reliability would have to be evaluated on the basis of data obtained elsewhere. The effects of such operating variables as dwell time, dose, and package type are related to the dosimetry of each type of gamma source.

The relative applicability of USAIRC HIFI data is indicated in Table II.

3. LINAC

Operation of the LINAC will permit a full evaluation of the engineering feasibility of linear accelerators--particularly if larger plants utilize multiples of the USAIRC LINAC, as must for the present be assumed.

The operation of the LINAC in the USAIRC will not necessarily establish it as the best type of accelerator for food irradiation. As Table II indicates, USAIRC data on shielding, materials handling, instrumentation, and both pre- and post-irradiation process requirements apply directly to the use of other types of accelerators. Hence, other factors would have to be evaluated for each type of accelerator. It appears, however, that these evaluations could be made by the commercial-accelerator manufacturers independently of USAIRC.

D. COST DATA

Since the USAIRC as currently planned will permit sustained operations typical of commercial food-processing operations, it will, if operated properly, yield practical information indicative of commercial operating costs for food irradiation. This does not mean that the actual costs at the USAIRC may be expected in commercial-scale operation. It means simply that from properly run USAIRC operations, the various commercial-scale cost elements can be usefully predicted.

TABLE II

TABLE II

FACTORS AFFECTING PERFORMANCE OF VARIOUS RADIATION SOURCES

	Larger Co 60 Sources		Other Promising Gamma Sources		LINAC		Others Accelerators	
	Direct[1]	Indirect[2]	Direct[1]	Indirect[2]	Direct[1]	Indirect[2]	Direct[1]	Indirect[2]
Accuracy of dosimetric design calculations	X[3]		X-------	X[4]	X			--[5]
Source efficiency	X		X-------	X[4]	X			--[5]
Source reliability	X				X			--[5]
Downtime of other equipment in irradiating facility	X		X		X			--[5]
Shielding design	X		X		X		X	
Materials-handling concepts	X		X		X		X	
Operating variables Dwell time Dose Package type	X		X-------	X[4]	X			--[5]
Instrumentation	X		X		X		X	
Process requirements, both pre- and post-irradiation	X		X		X		X	
Technology of source fabrication, shipment, installation, repair, or replacement	X			X	X			--[5]

1. "Direct" implies that USAIRC data can be extrapolated with confidence.
2. "Indirect" implies that USAIRC data will contribute to new design, but estimation or accumulation of additional data from other sources will be required.
3. X indicates whether data obtained at USAIRC will be directly or indirectly applicable to design of other sources.
4. Depends upon gamma source.
5. Could be determined by manufacturer independently of USAIRC.

Like the engineering data, the USAIRC cost data will obviously apply most directly to other cobalt 60 sources and to other LINAC sources. Shielding costs and costs of process modifications developed at the USAIRC will be applicable to other types of gamma sources or other accelerators. Data on other cost factors will require evaluation for each separate irradiating source. The relative applicability of USAIRC cost data is indicated in Table III.

E. SIZE VS REQUIREMENTS FOR TEST PURPOSES

Neither the scope nor the duration of an adequate testing program for irradiated foods has been defined; consequently, the rate of production it would take to support the program cannot be determined.

Military-ration components usually undergo two series of tests. One series, entirely controlled by the Quartermaster Corps, is called an engineering test. The other is observed by Quartermaster personnel, but is under the control of various military groups; it is called a user test. It appears that user tests are specified by CONARC only after or near the end of the engineering tests.

Rough estimates made by QMFACI representatives suggest that 285 tons of irradiated product per year may be required for its engineering tests.

The production required for user tests is open to conjecture. Some Quartermaster representatives feel that extensive testing should be anticipated. This seems reasonable, especially if the assumption concerning the quality of irradiated foods is optimistic and the acceptability of irradiated foods requires considerable evaluation. One member of the QM R&E Command believes that user tests might require amounts of meat, for example, sufficient to serve one-half pound per day to each of 15,000 men for about six months to a year. Assuming feeding on this scale for 300 days per year, about 1125 tons of meat per year would be required.

On the basis of these rough estimates, a total of about 1400 tons of meat per year would be required. This compares with an estimated 1800-ton output from the USAIRC on a 40-hour-week basis. If the estimated test quantities turn out to be realistic, the size of the USAIRC will be adequate for producing test materials.

TABLE III

TABLE III

FACTORS INFLUENCING CAPITAL AND OPERATING COSTS OF VARIOUS RADIATION SOURCES

	Larger Co 60 Sources		Other Promising Gamma Sources		LINAC		Other Accelerators	
	Direct[1]	Indirect[2]	Direct[1]	Indirect[2]	Direct[1]	Indirect[2]	Direct[1]	Indirect[2]
Source investment			Depends upon nuclide sources and current bookkeeping procedures		X			X
Shielding investment	X[3]		X		X		X	
Repair and maintenance source replenishment (labor and supplies)	X			X	X			X
Manpower	X			X	X			X
Operating Staff--Health Physics								
Overhead								
Utilities required	X			X	X			X
Cost of process modifications	X		X		X		X	
Space requirements	X			X	X			X

1. "Direct" implies that USAIRC data can be extrapolated with confidence.
2. "Indirect" implies that USAIRC data will contribute to new design, but estimation or accumulation of additional data from other sources will be required.
3. X indicates whether data obtained at USAIRC will be directly or indirectly applicable to design of other sources.

F. CONSEQUENCES OF SIZE REDUCTION

The foregoing indicates that the planned size of the USAIRC is adequate for determining engineering feasibility and practical cost data, and for producing (as well as can be estimated on the basis of current information) adequate quantities of meat for testing purposes. In our opinion, engineering-feasibility and cost data could probably be obtained from a somewhat smaller plant. We have not studied the minimum plant size that would be adequate for test purposes; rather, we have examined the variations in capital requirements as plant size is reduced.

Figure 1 shows the approximate variation of LINAC costs with capacity. The costs include all elements of the Varian contract, as estimated by Varian Associates. They also include the LINAC housing costs, as supplied by QMRPA. The accelerator itself is the most variable element; the costs of the other components vary little over the capacity range. On this basis, a 50% capacity reduction results in a 16% cost reduction; a 67% capacity reduction results in a 20% cost reduction. The savings are small in comparison with the loss of capacity.

Figure 2 shows the variation in the capital cost of the HIFI with capacity, based upon rough estimates made by QM and AEC personnel and agreed to in principle by representatives of Curtiss-Wright Corporation. The principal variable cost element is the amount of radioactive cobalt contained in the source. Depending upon the source, a 67% capacity reduction would decrease capital costs by only 14-21%.

From inspection of the USAIRC layout drawing, it is evident that little could be saved by reduction of the food-preparation area. The proposed laboratory and office areas appear to be required for the proper operation of the USAIRC in fulfilling its objectives, regardless of the size of the pilot plant.

G. CONCLUSIONS

If engineering-feasibility and practical cost data plus the production of substantial quantities of food for test purposes continue to be important objectives of the indicated food program, the facility planned for the USAIRC will be adequate.

The reduction in cost resulting from a reduction in scale would be small in comparison with the reduction in throughput capacity. At this time, despite the possibility that the plant may be somewhat larger than required, we see no point in trying to reduce its size.

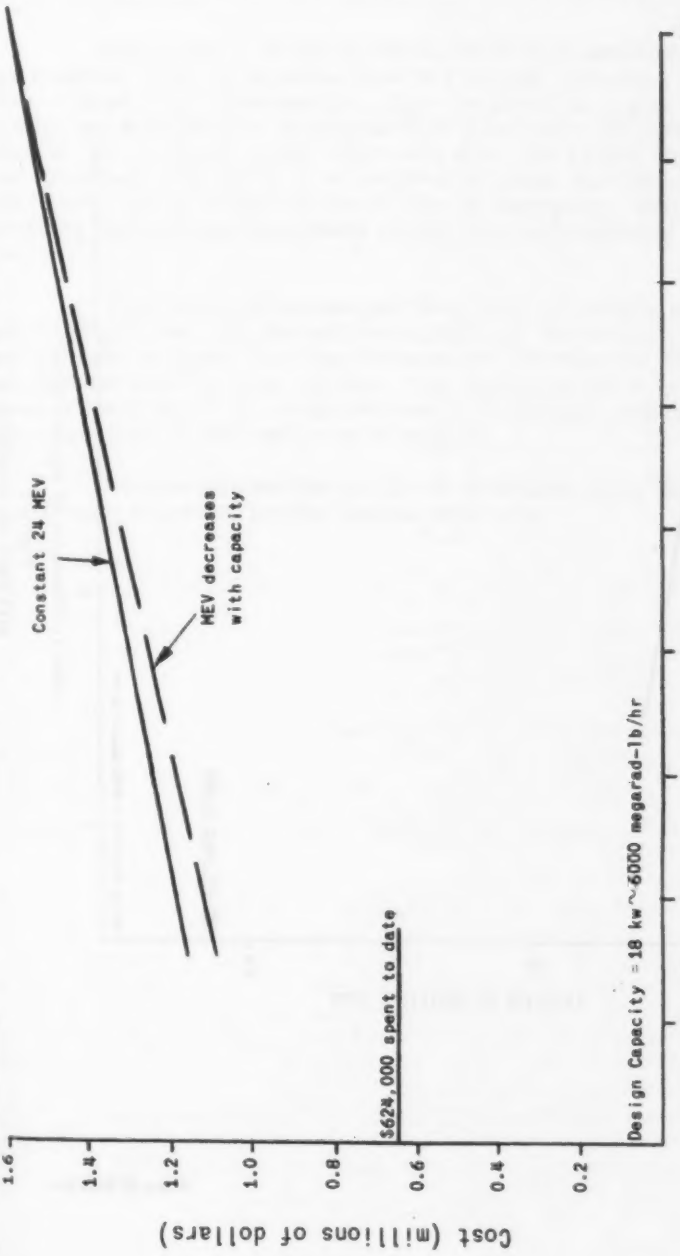


Figure I
LINAC COST VS CAPACITY

Figure 2
HIFI COST VS CAPACITY

Arthur D. Little, Inc.

Alternatively, if the objectives of the food-irradiation program are modified, it would be useful to build a USAIRC containing only one of the two types of radiation source. Since the LINAC is nearer completion, it might seem reasonable to continue with it and defer the HIFI. In addition, as later sections of this report will show, the LINAC investment and operating costs appear to be as low as or lower than the comparable HIFI costs, and it is expected that in time of emergency, additional LINAC facilities could be generated more rapidly than corresponding HIFI facilities.

When the experimental and demonstration periods were over, and if design production capacity were achieved, the facility could produce enough meat to supply about four divisions (15,000 men per division) with one pound of meat per man per day. This might turn out to be useful in an emergency, since our study indicates that additional radiation facilities might take at least two years to activate.

We conclude that the facility is of adequate size, but is not significantly oversized for the planned objectives.

Figure 2
HIFI COST VS CAPACITY

V. LOGISTIC EVALUATION

In our evaluation of the logistic consequences of the availability of irradiated sterilized meat in comparison with refrigerated meat, we have considered the savings in terms of production capability, men, and materiel. The additional consequences of making irradiated sterilized meats available to military areas where refrigerated meats cannot be made available (under the current feeding system), are noted. We have not attempted to compare the consequences of supplying irradiated and refrigerated meat to forward combat areas; refrigerated meats would not be supplied regularly to those areas, and the comparison would be meaningless.

Nor have we evaluated the consequences of the availability of irradiated sterilized meat in the many tactical situations that can be postulated for future military operations. An evaluation of this kind would require the use of operations-research methods not feasible within the scope of our assignment.

A. PRODUCTION CAPABILITY VS EMERGENCY SITUATION

In reviewing the possible irradiating sources for the USAIRC, we have found that the choice of the LINAC and the HIFI is sound for both technical and economic reasons.

The capability for producing irradiated sterilized foods and the time required for generating or expanding the country's production capability are matters of logistic importance. There is no plant capacity now, and no plants suitable for the radiation sterilization of meat will be sponsored by food companies until major technological advances are made at USAIRC.

We estimate that with appropriate military priority, the activation of irradiating facilities utilizing cobalt 60 would require about two years. Without a military priority it would be necessary to obtain cobalt 60 from commercial suppliers. The commercial capacity for producing cobalt 60 is small relative to megacurie military requirements; would take well over three years to accumulate adequate amounts. Unless cobalt 60 irradiation facilities are somehow provided in anticipation of future emergencies, they can not be used in emergencies of short duration.

Facilities utilizing electron accelerators could be put up within a year. It is generally agreed that linear accelerators are the most suitable types for delivering beams of 10 Mev or higher. Therefore, they can best meet current QMC specifications. In an emergency, however, the availability of klystrons needed in the construction of accelerators might temporarily be limited by high-priority requirements for other purposes. Other types of accelerators might become useful if QMC package specifications were altered to permit the use of lower-voltage accelerators while assuring adequate penetration.

Table IV indicates the relative suitability, cost, and availability of numerous irradiating sources, listed in approximately decreasing order of over-all suitability. Brief comments on this comparison are given in Appendix C.

In general, it can be said that it would take at least one to two years to put up the most promising type of facility.

B. ZONE OF INTERIOR TO OVERSEAS DEPOT

This section is concerned with a comparison of the costs of irradiated, frozen, and thermally processed meat delivered to an overseas depot. The cost of the irradiated meat is an ADL estimate; the costs for the other processes represent typical industry experience. The estimates of shipping and storage costs are derived from a recent QMFACI report and reflect government experience. The packaging data are based on information received directly from QMFACI. Raw-material and preparation costs are assumed to be the same for all processes.

1. Estimated Processing Costs for Irradiated Meat

We have estimated the approximate costs of irradiating boneless beef packed in a standard 6" x 16" x 24" package, in both the LINAC and the HIFI. Two plant sizes were assumed, one equivalent to a moderate-to-large commercial plant, the second to a very large commercial plant. The first one would adequately supply meat at the rate of one pound per man per day for just over two Division Slices, each comprising 50,250 men. The second would supply over four Division Slices, or roughly one independent Corps, on the same basis.

Over the size range examined, the scale of the plant has little effect on the cost of irradiation. Table V summarizes the estimated costs and shows the effect of variations in the price of cobalt 60 for the moderate-to-large plant.

TABLE IV

COMPARISON OF LARGE RADIATION SOURCES
OF 100-200 kw CAPACITY

Radiation Source	Technical Suitability for Current QMC Specifications	Relative Cost	Estimated Delivery Period 1 yr	2 yr	3 yr
LINAC	good	good	X		
Accelerators (all other types)	fair-poor	good	X		
Cobalt 60	good	fair			
With no military priority			-	-	-
With high military priority in a nuclear production facility			-	X	
Cesium 137	fair	fair		X[1]	
"Zr-Nb"[2]	poor	poor		X	
Scandium	fair	poor	X		
Spent fuel elements	poor-fair	poor-fair	X		
Gamma loops					
Sodium	poor	fair		X	
Indium	fair	poor			X
Gaseous fission products	poor	poor			X
Bremstrahling from accelerator	poor	poor		X	

1. Assumes sufficient cesium 137 exists at Hanford, Washington.

2. Mixed fission products of the zirconium - niobium group.

TABLE V

ESTIMATED COSTS OF IRRADIATING MEAT

Bases: Boneless Beef in Standard Package (6" x 16" x 24")
Plant Capacity--43 million lb/yr[1]

	Cents per Pound	
	Manufacturing Cost Only[2]	Including Return On Investment[3]
LINAC	2.58	5.27
HIFI		
Co 60 @ $0.2775/curie	2.84	5.37
0.50	4.64	8.76
0.75	6.64	12.54
1.00	8.74	16.32
2.00	16.74	31.64

1. Adequate to feed 2-1/3 Division Slices of 50,250 men each, at 1 lb/man/day. Representative of moderate-to-large commercial plant.

2. Represents 10% depreciation plus operating costs. No allowance for administrative and selling costs or for return on investment.

3. Represents 10% depreciation and operating costs plus 20% return on initial plant investment before taxes. No allowance for administrative and selling costs.

Two sets of estimates are shown. One is based upon manufacturing costs alone, with no provision for administrative and selling costs or for return on investment. The other includes provision for a 20% return on initial investment before taxes--which is appropriate for purposes of comparison in this study. See Appendix D.

The estimates based upon manufacturing cost alone indicate processing costs of about 2.6¢ per pound for the LINAC and of 2.6 to 16.7¢ per pound (depending upon the cost of cobalt 60) for the HIFI. Estimates including provision for a return on investment are 5.3¢ per pound for the LINAC and 5.2 to 31.6¢ per pound for the HIFI. The cost of processing frozen or thermally processed meats is in the range of fractions of a cent per pound.

2. Packaging

On the basis of present knowledge, the only reliable container for irradiated meats for military purposes is the metal can. Representatives of the QMFACI believe that a suitable, economical plastic container will ultimately be found. This plastic package could be used as a liner for a paperboard V3s container.

Table VI indicates the volume (cube), the weight, and the costs of typical packages associated with a given weight of fresh meat processed by different methods. These values of cube and weight are the bases for the transportation costs estimated in Section 3 below. Thermal and irradiated cooked meats are assumed to have shrunk 30%. The weight and volumes are those associated with the product remaining after 50 pounds of fresh meat has been cooked. It is assumed that enzyme-deactivated meats do not shrink.

When proper comparisons are made, it is clear that the cube and weight of packaged irradiated meat are essentially the same as for frozen or thermally processed meats. For example, cooked irradiated meat in No. 10 cans compares with thermally processed meat in No. 10 cans. Irradiated enzyme-deactivated meat in rectangular tins or in a V3s box with a plastic liner compares with frozen meat in a V3s box.

The package cost for irradiated enzyme-deactivated meat is higher than for frozen meat. The package cost for irradiated cooked meat in cans is comparable with the package cost for thermally processed meat in cans.

TABLE VI

CUBE-WEIGHT - PACKAGE COST

Basis: Fresh Boneless Beef Equivalent

	Volume/50 Lb (cu ft)	Weight/50 Lb (lb)	Cost/50 Lb ($)	Cost/Lb (¢)
Frozen				
V3s	1.2	52.8	0.40	0.8
Thermal				
#10 can	1.1	42.5	1.44	2.9
Irradiated (enzyme-deactivated)				
#10 can	1.5	60.8	2.05	4.1
Rectangular tin	1.1	55.4	2.08	4.2
V3s + plastic liner	1.0	53.5	0.90	1.8
Irradiated (cooked)				
#10 can	1.1	42.5	1.44	2.9
Rectangular tin	0.7	38.8	1.46	2.9
V3s + plastic liner	0.7	37.4	0.63	1.3

In general, it appears that even if plastic packaging materials are developed, the package cost for irradiated meats will be equal to or greater than that for frozen or thermally processed meat.

3. Estimated Shipping Cost

In estimating the shipping cost from the point of production to an overseas depot, we assumed that irradiated meats require no refrigeration and can therefore be shipped as nonperishable freight. Our estimates of shipping costs include U. S. land transportation, port handlings, ocean freight, and overseas inland transportation. We used the rate data contained in the August 29, 1957, report by QMFACI covering a study of the potential savings in shipping costs when irradiation is used in lieu of refrigeration. The current validity of these rates was orally confirmed by the Chicago Military Subsistence Market Center through a representative of QMFACI.

Shipping costs from an assumed plant located in Kansas City, Missouri, to Europe, the Caribbean, and the Far East were computed. The costs to Europe (Bremerhaven, Germany) are representative; they are shown in Table VII.

It is evident that the shipping cost depends upon the container and the type of processing employed. The shipping cost for cooked meat is lower than that for uncooked counterparts because of the shrinkage caused by cooking. The cost of shipping irradiated uncooked meat is lower than that for frozen meat. The cost of irradiated cooked meat is the same as that for thermally processed meat.

4. Estimated Storage costs

On the basis of the actual costs incurred during fiscal 1958, as quoted in the QMFACI report referred to above, the cost of storing perishables was about 0.66¢ per pound. The storage cost for nonperishables was about 0.44¢ per pound. It is possible that these figures represent shorter storage periods for perishables than for nonperishables. Rates for refrigerated storage are nearly four to five times the rates for storage of nonperishables. Inasmuch as these costs have a small effect upon our over-all costs of shipping to an overseas depot, further analysis is not warranted.

TABLE VII

ESTIMATED SHIPPING COSTS

Basis: Equivalent Fresh Meat--Kansas City, Mo., to Europe (Bremerhaven)

Process	Package	Shipping Cost (¢/lb)
Frozen		
	V3s	6.4
Thermal		
	#10 can	4.0
Irradiated (uncooked enzyme-deactivated)		
	#10 can	5.6
	Rectangular can	3.9
	V3s with plastic liner	3.5
Irradiated (cooked)		
	#10 can	3.9
	Rectangular can	2.7
	V3s with plastic liner	2.5

5. Losses

Government figures have consistently shown that losses during shipping and storage are less than 0.5%. For the purposes of our comparison we have assumed a 1-1/2% loss for frozen meat and no losses for thermally processed meats and irradiated meats. Assuming a cost of 85¢ per pound for raw material, a loss of 0.5% represents an increase of 0.46¢ per pound in the cost of frozen meat delivered to the overseas depot.

6. Summary of Costs to Overseas Depot

Section A of Table VIII summarizes as a subtotal the costs, based upon manufacturing costs alone, of processing, packaging, shipping, storage, and loss for frozen, thermally processed, and irradiated meats in the case of cobalt 60 costing $1.00 per curie for meat production from a plant of medium-to-large capacity. The cost of irradiated meat is 1.7 to 11.9¢ per pound higher than that of frozen meat, and 2.8 to 13¢ per pound higher than that of thermally processed meat, on the basis of equivalent fresh meat. Section B of Table VIII compares the costs when provision is made for return on investment.

As we have said, the costs of raw material and preparation were assumed to be the same for all processes. The total figures shown include typical raw-material and preparation costs; they portray the magnitude of cost variation. Provision for return on investment would increase the indicated costs by the differences shown in Table V.

Section A of Table IX summarizes the subtotals discussed above for cases covering meat irradiated by a LINAC and by a HIFI using cobalt 60, over a range of cobalt 60 costs. The table indicates that the cost of irradiated meat delivered to an overseas depot is equal to or greater than the cost of frozen or thermally processed meat for all cases studied, except cooked irradiated meat in a package to be developed in the future. It further indicates that the estimated costs when the LINAC is used are comparable to the costs when cobalt 60 at the current low price is used. Section B of Table IX shows comparable costs when provision is made for return on investment.

On the basis of this evaluation, the higher processing and packaging costs for irradiated meats counterbalance or outweigh the savings due to the elimination of refrigeration.

TABLE VIII

TABLE VIII

BREAKDOWN OF COSTS TO OVERSEAS DEPOT
(cents/lb of equivalent fresh meat)

Bases: Cobalt 60 @ $1.00/curie
Plant capacity: 43 million lb/yr
Kansas City, Missouri, to Bremerhaven, Germany

A. PROCESSING AT MANUFACTURING COST WITH NO RETURN ON INVESTMENT

Process------Frozen	Thermal	IR-ED[1]	IR-ED[1]	IR-ED[1]	IR-C[2]	IR-C[2]	IR-C[2]
Package-------V3s	#10 Can	#10 Can	Rect. Can	V3s-P[3]	#10 Can	Rect. Can	V3s-P[3]
Processing	0.2	0.2	10.4	8.7	8.7	7.3	6.1	6.1
Packaging	0.8	2.9	4.1	4.2	1.8	2.9	2.9	1.3
Shipping	6.4	4.0	5.6	3.9	3.5	3.9	2.7	2.5
Storage	0.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Loss	0.5	0	0	0	0	0	0	0
Subtotal	8.6	7.5	20.5	17.2	14.4	14.5	12.1	10.3
Raw Material	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0
Preparation	1	1	1	1	1	1	1	1
Total	94.6	93.5	106.5	103.2	100.4	100.5	98.1	96.3

TABLE VIII (Continued)

B. PROCESSING AT MANUFACTURING COST WITH PROVISION FOR RETURN ON INVESTMENT

Process------	Frozen	Thermal	IR-ED[1]	IR-ED[1]	IR-ED[1]	IR-C[2]	IR-C[2]	IR-C[2]
Package-------	V3s	#10 Can	#10 Can	Rect. Can	V3s-P[3]	#10 Can	Rect. Can	V3s-P[3]
Processing	0.2	0.2	19.6	16.3	16.3	13.7	11.4	11.4
Packaging	0.8	2.9	4.1	4.2	1.8	2.9	2.9	1.3
Shipping	6.4	4.0	5.6	3.9	3.5	3.9	2.7	2.5
Storage	0.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Loss	0.5	0	0	0	0	0	0	0
Subtotal	8.6	7.5	29.7	24.8	22.0	20.9	17.4	15.6
Raw Material	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0
Preparation	1	1	1	1	1	1	1	1
Total	94.6	93.5	115.7	110.8	108.0	106.9	103.4	101.6

1. IR-ED = Irradiated enzyme-deactivated.

2. IR-C = Irradiated cooked.

3. V3s-P = V3s box with plastic liner.

Arthur D. Little

TABLE IX

3. V3s-P = V3s box with plastic liner.

TABLE IX

COMPARISON OF RELATIVE COSTS OF MEAT DELIVERED TO OVERSEAS DEPOT
(cents/lb of equivalent fresh meat)

Bases: Cobalt 60 @ $1.00/curie
Plant capacity: 43 million lb/yr
Kansas City, Missouri, to Bremerhaven, Germany

A. EXCEPT RAW MATERIALS PLUS PREPARATION COSTS; PROCESSING AT MANUFACTURING COST WITH NO RETURN ON INVESTMENT

Process	Frozen	Thermal	IR-ED[1]	IR-ED[1]	IR-ED[1]	IR-C[2]	IR-C[2]	IR-C[2]
Package	V3s	#10 Can	#10 Can	Rect. Can	V3s-P[3]	#10 Can	Rect. Can	V3s-P[3]
	8.6	7.5						
LINAC			13.2	11.1	8.3	9.4	7.8	6.0
HIFI								
Co 60 @ $ .2775/c			13.4	11.3	8.5	9.6	8.0	6.2
.50			15.6	13.1	10.3	11.1	9.2	7.4
.75			18.0	15.1	12.3	12.8	10.6	8.8
1.00			20.5	17.2	14.4	14.5	12.1	10.3
2.00			30.1	25.2	22.4	21.2	17.7	15.9

TABLE IX (Continued)

B. EXCEPT RAW MATERIALS PLUS PREPARATION COSTS; PROCESSING AT MANUFACTURING COST WITH PROVISION FOR RETURN ON INVESTMENT

Process-----	Frozen	Thermal	IR-ED[1]	IR-ED[1]	IR-ED[1]	IR-C[2]	IR-C[2]	IR-C[2]
Package------	V3s	#10 Can	#10 Can	Rect. Can	V3s-P[3]	#10 Can	Rect. Can	V3s-P[3]
	8.6	7.5						
LINAC			16.5	13.8	11.0	11.7	9.7	7.9
HIFI								
Co 60 @ $ .2775/c			16.5	13.9	11.1	11.8	9.8	8.0
.50			20.7	17.3	14.5	14.6	12.2	10.4
.75			26.1	21.0	18.2	17.7	14.8	13.0
1.00			115.7	110.8	108.0	106.9	103.4	101.6
2.00			48.0	40.1	37.3	33.7	28.1	26.3

1. IR-ED = Irradiated enzyme-deactivated.
2. IR-C = Irradiated cooked.
3. V3s-P = V3s box with plastic liner.

Arthur D. Little

C. THEATER OF OPERATIONS

Any logistic advantage attributable to irradiated meats in a wartime theater of operations depends largely upon two important factors.

The first factor is the availability of such meat to all theater areas at times when refrigerated meat cannot be supplied. In accordance with one of the assumptions imposed upon this study, irradiated meats may be regarded as equivalent to their refrigerated counterparts. Refrigerated meats are generally considered more acceptable to troops than thermally processed (or canned) meats. On the basis of current information, it is impossible to estimate quantitatively the expected increases in troop effectiveness resulting from improved rations. Qualitatively, however, the consensus seems to be that improved rations will contribute to greater troop effectiveness. On the basis of the above assumption, it is immediately evident that irradiated meats offer the advantage of making improved rations components available.

The second factor is the elimination of refrigeration. Field storage facilities are not required. Refrigerated-storage equipment and corresponding operating and maintenance personnel, supplies, and equipment are no longer needed, nor is refrigerated-transport equipment.

1. Basis for Evaluation

The basis we used for evaluating the consequences of eliminating refrigeration by the use of irradiated meats in a wartime theater of operations is one Division Slice plus one Wing Slice in a stable situation. This was suggested by a representative of the Command and General Staff College at Fort Leavenworth as being the typical group used for logistic planning purposes. The greatest utilization of refrigerated meats and other perishable rations occurs after the assault phase and theater buildup, when a stable condition is achieved.

Figure 3 portrays the typical distribution of troops in a Division Slice and one Wing Slice. Of the total of 50, 250 men involved, 20, 000 are in the division and contact areas, 15, 500 are in the army and corps area, and 14, 750 are in the communications zone. Also shown on Figure 3 are representations of the current feeding system and of one proposed by QMC on the basis of irradiated and dehydrated foods.

2. IR-C = Irradiated cooked.
3. V3s-P = V3s box with plastic liner.

Figure 3

COMPARISON OF CURRENT AND PROPOSED FEEDING SYSTEM IN THEATER OF OPERATIONS

COMPARISON OF CURRENT AND PROPOSED FEEDING SYSTEM IN THEATER OF OPERATIONS

Depots for Class I supplies (rations) and the number of days supply consistent with current doctrine concerning increased dispersion are indicated. Transportation from base depot is usually under the Transportation Corps. Shipment between other depots is usually under the QMC. Shipments may go directly from any one area depot to any other depot, supply point, or distributing point farther forward. The zones need not be contiguous and may be separated by considerable distances.

In the current feeding system, A rations and modified B rations, which require trained cooks, preparation equipment, and refrigeration facilities, are used as far forward and as often as practical. B rations require no refrigeration, but do require trained cooks and preparation equipment; therefore, they are indicated as being used farther forward than A rations or modified B rations. The "5-in-1" ration is similar to the B ration. The C ration requires only minor preparation equipment. The assault packet requires none of these.

Under this feeding system it can be assumed that refrigerated meats are fed 5% of the time in the forward areas, about 33% of the time in the army and corps rear areas, and about 90% of the time in the Communications Zone. On an average, then, 19,470 men (38%) are served refrigerated meats per day. On the basis of an allowance of about one pound per man per day, this amounts to a requirement of about 10 tons per representative slice per day. The savings in terms of dollars, materiel, and men by the elimination of refrigeration are those associated with handling about 10 tons of meat per day.

Under the new feeding concept, irradiated and dehydrated meats are visualized as being used about as far forward as is the current B ration. As in the case of the B ration, refrigeration would not be required, but trained cooks and food-preparation equipment would. The "prepared meals" are visualized as being fed about as far forward as current C rations. These "prepared meals" are based largely upon the concept of precooked dehydrated meals that can be reconstituted by the simple addition of hot water. Minor preparation equipment is required. Individual meals are based upon irradiated components and are intended to be eaten cold, out of hand.

2. Estimated Savings Due to Elimination of Refrigeration

The estimates derived below are based upon information received at the Command and General Staff College, plus that supplied by various members of the Office of the Quartermaster General, Washington, D. C., and upon information contained in various Army Field Manuals.

a. QM Field Refrigeration Equipment

The value of QM refrigerated field storage equipment for meat associated with 50,250 men in a representative Division Slice plus one Wing Slice is about $65,000. This is about 57% of the value of all QM refrigerated field storage equipment. With irradiated meats this investment could be entirely eliminated. The meat could be stored in the same manner as other nonperishable food items.

The approximate operating cost associated with the above equipment--involving operating and maintenance parts and materials plus utilities--amounts to about $152 per day.

Elimination of field storage boxes plus the associated QM refrigerated-transport equipment would save 28 men or make them available for other duties.

About seven refrigerated 7-1/2-ton semitrailers are used for the transport of meat by the QMC. Irradiated meats would not permit the full elimination of the investment for these trailers, but the irradiated meat could be shipped in nonrefrigerated vehicles. As shown earlier, the cube and weight of irradiated meats are about the same as for frozen meat in comparable packages. Savings in transport vehicles would depend largely upon the type of vehicle used to replace the refrigerated semitrailers. We have assumed that irradiated meats would be transported in a 12-ton cargo trailer. This trailer has twice the cargo-carrying capacity of a 7-1/2-ton refrigerated semitrailer. Three and a half 12-ton cargo trailers at $6000 each are equivalent to seven "refer" units at $8600 each. This saves a net investment of about $39,000.

Assuming that each vehicle uses two men, 12-ton cargo trailers would release seven men for other duties. The release of men is entirely dependent upon the cargo capacity of the vehicle used to handle irradiated meat. The use of a vehicle of the same capacity as the refrigerated semitrailer would save no men. The use of a smaller vehicle would require more men.

b. Transportation Corps Equipment

Approximately three 7-1/2-ton refrigerated semitrailers are used by the Transportation Corps for the shipment of refrigerated meat for one representative Division Slice. On the basis of the reasoning applied above, three semitrailers could be replaced by one and a half 12-ton cargo trailers, at a net saving of about $15,000; three men could be released for other duties.

c. Reduction in Spoilage

The amount of perishable meat (or other food) lost by spoilage in a theater of operations is not definitely known. Representatives of the QM R&E Command have suggested that 5% is representative of field experience. Assuming that this amount of spoilage is attributable to inadequacies or failures of refrigeration equipment, and assuming that this amount of spoilage would be eliminated by the use of irradiated meat, the savings per Division Slice would be about $900 per day. This estimate of savings is optimistic, however, because irradiated meat is subject to spoilage whenever its package is opened or punctured.

Inasmuch as the proposed feeding system implies that irradiated meats would be fed as far forward as is the current B ration, and since the two systems require the same kind of personnel and equipment for food preparation, we visualize no decrease in equipment or personnel attributable to irradiated meats.

If cooked irradiated meats were supplied, some reduction might become possible. On the other hand, if it were deemed advisable to be prepared to utilize local meats in the theater of operations or meats from sources outside the Zone of the Interior, little if any reduction could be expected.

d. Summary of Logistic Consequences of Irradiated Meat

Table X summarizes the increase or decrease in the costs of irradiated meats delivered to an overseas depot in a theater of operations under stable conditions, in terms of daily costs for a representative Division Slice plus one Wing Slice. Based upon the estimates in Table VIII, values are shown for the two most advantageous cases: (a) irradiated enzyme-deactivated meat in a V3s box with a plastic liner and (b) irradiated cooked meat in the same package.

TABLE X

SAVINGS (-) OR ADDED (+) EXPENSES RELATIVE TO CURRENT FEEDING SYSTEM
FROM ZONE OF INTERIOR TO OVERSEAS DEPOT
BY USE OF IRRADIATED MEAT
(dollars/day)

Bases: One Division Slice plus One Wing Slice
Equivalent fresh boneless beef
Package: V3s box with plastic liner
Irradiated meat replaces both refrigerated and thermally processed (canned) meat

Facility	Enzyme-Deactivated Meat		Cooked Meat	
	No Return On Facility Investment	With Return On Investment[1]	No Return On Facility Investment	With Return On Investment[1]
LINAC	+188	+1552	-928	-13
HIFI				
Co 60 @ $ .2775/c	+188	+1492	-928	-64
.50	+1193	+3295	-265	+1240
.75	+2195	+5155	+439	+2546
1.00	+3250	+7060	+1191	+3850
2.00	+7270	+14830	+4000	+9230

1. See Appendix D.

Arthur D. Little, Inc.

All figures reflect the replacement of 19,470 lb/day of refrigerated meat plus 30,780 lb/day of canned meat with irradiated meat.

The use of irradiated meat would save an investment in materiel of about $119,000 which if amortized over 10 years would amount to $33 per day. Another $152 per day would be saved in direct operating costs; to the extent spoilage is reduced, moreover, an additional amount would be saved, but data on the spoilage of perishables is not available. For purposes of this study, we have assumed that the loss would be 5% lower than for refrigerated meat. This would add a saving of $900 per day. These savings total $1085 per day.

The use of irradiated meats might release up to 38 men for other duties.

If the estimates are reasonable, the dollar savings realizable in the theater of operations balance out the added cost of delivery to a Communication Zone, provided the cost of cobalt 60 does not exceed certain values. The following breakeven points occur:

1. When irradiation costs are based on manufacturing costs alone, and on cobalt 60 costs just under 50¢ per curie for enzyme-deactivated meat and just under $1.00 for cooked meat.

2. When irradiation costs are based on manufacturing costs plus provision for a return on investment, and on cobalt 60 costs less than 28¢ per curie for enzyme-deactivated meat and just under 50¢ for cooked meat.

The linear accelerator shows a net saving for enzyme-deactivated meats if no provision is made for a return on investment, and for both cases involving cooked meats.

It should be noted that Table X reflects the use of a packaging technique not yet available for irradiated meats. The use of any other package studied would substantially increase the costs shown.

The data in the table underline the advantage of irradiated cooked meats over irradiated enzyme-deactivated meats--reflecting the effect of shrinkage in weight and volume during cooking prior to irradiation and shipment. This constitutes a logistic advantage over uncooked

1. See Appendix D.

irradiated meats, in that the bulk and weight per unit of equivalent fresh meat are reduced. Inasmuch as cooking requires less severe thermal treatment than canning (thermal processing), it would favorably affect the quality of irradiated meats relative to canned meats.

Since the advantages and disadvantages of irradiated meat discussed above essentially counterbalance each other, the net advantage realizable by the use of irradiated meats seems to depend upon the possibility of providing improved rations that can also be expected to give minimum losses through spoilage.

3. Assault Phase and Theater Buildup

During an assault phase, refrigerated meats are usually not fed, but they are introduced into the theater as rapidly as possible during the buildup phase. Comparison of irradiated meats with refrigerated meats in terms of dollars, men, and materiel for the assault phase is not appropriate. But as the use of refrigerated meats gradually increases in the buildup period, the comparisons approach those developed above for the stable situation.

The principal advantage of irradiated meats is that they can be made available when refrigerated meats can not. Low loss is an added advantage.

4. Peacetime Military Use of Irradiated Meat

During peacetime, considerable amounts of meat and other perishables for field forces may be procured locally. Refrigerated-storage space is frequently available on a lease or rental basis, and refrigerated-transport equipment is readily available. Because of the likelihood of a higher total cost, therefore, irradiated meat would have no advantage over refrigerated meat.

However, stockpiles of food are maintained for emergency use during peacetime. Thermally processed rather than refrigerated meats are stockpiled. If not utilized before they become unfit for feeding purposes, they are dumped. To the extent that irradiated meats have a longer storage life than canned meats, they offer real economic advantages. The storage life of irradiated foods has not been determined but indications are that it will be substantially longer than the storage life of ordinary canned meats.

VI. CONCLUSIONS

On the basis of our study we conclude that in terms of dollars, men, and materiel, the logistic advantages of irradiated meat are essentially counterbalanced by disadvantages when radiation economics are on a commercial basis.

The principal advantage appears to come from the availability of improved rations with minimum expected spoilage in areas where at times refrigerated or "fresh-like" meals are not available.

In the light of current knowledge, there is no basis for choosing either frozen or irradiated meat to the exclusion of the other; costs are about the same within the limits of accuracy of available data. In the case of irradiated meat, freedom from the need for refrigerated storage and transportation may have logistic implications in military planning, entirely apart from cost considerations; for example, less rigid scheduling, greater ability to alter plans on short notice, and greater flexibility in transportation may have a substantial significance that our study could not take into consideration.

Since our study indicates that radiation sterilization of meat may equal or excel refrigeration as a technique in military feeding systems, it seems reasonable for military planners to foster research and development work on this subject and to try to interest commercial producers. The costs and circumstances associated with the project are such that commercial interests are unlikely to go forward on their own, and government initiative and financial support are required.

If the Department of the Army has over-all interest in the military significance of irradiated food, it would do well to examine the possible use of irradiated food as a source of stockpiled supply in the event of a Zone of the Interior disaster of considerable magnitude.

APPENDIX A

THE PRINCIPAL OBJECTIVES OF USAIRC[1]

1. To provide a prototype facility to determine the economic factors in mass production of irradiated foods.

2. To determine which specific foods or other items should be irradiated by electrons and which should be treated by gamma rays for the most effective and economical process.

3. To provide a supply of irradiated foods for:

a. Testing acceptance, palatability, and storage characteristics;

b. Troop consumption.

4. To promote interest and participation of industry in food-irradiation processes.

5. To provide irradiation services to Department of the Army Technical Services.

---

1. Extracted from "Descriptive Brief, U. S. Army Ionizing Radiation Center, Sharpe General Depot," QMRPA, QMR&E Command, November 1958.

APPENDIX B

ESTIMATED PRODUCTION RATES OF RADIATION SOURCES AT USAIRC[1]

(in pounds per hour at megarad doses in selected containers)

High-Intensity Food Irradiator					Container Type	Linear Accelerator (24 Mev)				
Megarads						Megarads				
2	3	4	5	6		2	3	4	5	6
Pounds Per Hour						Pounds Per Hour				
3000	2000	1500	1200	1000	Standard Package (6" x 16" x 24")	3000	2000	1500	1200	1000
2480	1650	1240	990	824	No. 10 Can, Uncased (7" high)	2415	1610	1207	966	805
2170	1440	1080	865	724	No. 2-1/2 Can, Uncased (4-11/16" high)	1725	1150	862	690	575
2320	1540	1160	925	770	No. 10 Can, in Cartons (7-1/2" high)	2175	1450	1088	870	725
1830	1200	910	725	610	No. 2-1/2 Can, in Cartons (5-1/16" high)	1450	966	725	580	483

1. Extracted from "Special Briefing for The Food Advisory Group, Office of the Director of Defense Research and Engineering, on Current Plans for U. S. Army Ionizing Radiation Center," by the Quartermaster General, June 17, 1959.

APPENDIX C

COMPARISON OF GAMMA SOURCES

A. INTRODUCTION

The radiation power visualized for the production of meat for military purposes is in the order of a few hundred kilowatts. It is known that with existing technology, such levels of radiation power could be made available from the LINAC within a year or so, in the event of a military need for additional radiation power. On the other hand, the ready availability of radionuclide sources in the equivalent range of hundreds of kilowatts (that is, tens of megacuries of cobalt 60 equivalent) is not so evident. We estimate that the present U. S. capacity for producing cobalt 60, with a high priority in a government nuclear production facility such as Savannah River, is less than 1 megacurie per year. Comparable British and Canadian capacities exist but are not counted on for wartime emergency supply. We understand that if cobalt 60 were given a higher priority than nuclear-weapons materials produced in reactors, much more could be produced per year. In a limited war or in peacetime, irradiated food might be useful and a sufficient priority might be given cobalt 60 to assure an adequate supply. We have reviewed the situation with respect to other radionuclides to see whether they offer adequate technical merit and greater availability in large quantities. These findings are summarized briefly in the following sections.

B. CESIUM 137

This nuclide is produced in quantities of "megacuries per year" at Hanford, Washington, mixed with other partially separated fission products. Because of the lower energy of its radiation (0.67 Mev compared with about 1.2 Mev for cobalt 60) and the fact that it emits fewer photons per disintegration, it takes more than four curies of cesium 137 to irradiate food at the same rate as one curie of cobalt 60. While processes for the separation of cesium from fission products have been demonstrated, the only plant available for quantity separation is at Oak Ridge. This plant has a capacity of the order of 200,000 curies per year. In several months Hanford Engineering Works could convert an existing idle facility into a separation plant with an annual capacity of several million curies of cesium 137. Techniques for encapsulating the cesium salt have been demonstrated, but not on a large scale. The cost of cesium 137 is largely a matter of government accounting, but we estimate

the cost for an installed cesium 137 source to be equal to that of an equal wattage of cobalt 60. The half-life of cesium 137 is 33 years; this compares favorably with cobalt 60's four years. According to Dr. Bernard Manowitz at Brookhaven National Laboratory, cesium 137 could sterilize food according to the Quartermaster Corps' requirements if some slight lengthening in the dwell time in the cesium source were tolerable. On the whole, then, cesium 137 constitutes a reasonable alternative radiation source if the amount available is adequate. For a more detailed discussion of the merits, economics, and availability of these sources, see Chapter 12 (and elsewhere) of Radiation: A Tool For Industry, an Arthur D. Little report to Emerson Radio and Phonograph Company and General Electric Company (Hanford Atomic Products Operation), January 1959.

C. ZIRCONIUM-NIOBIUM

This mixture of zirconium and niobium fission products has a 65-day half-life and 0.7 Mev gamma radiation; it is present in multi-megacurie quantities at Hanford, Washington. The cost of producing it in fused stable sources has been estimated at 4¢ per curie in large quantities. If a large quantity of nuclides were desired for a crash program and cobalt 60 and cesium 137 were not available, zirconium-niobium could be considered. There is no separation plant as yet, but one could be converted from existing equipment in a reasonable time. Shipping costs for replacing this relatively short-half-life material would considerably increase the apparently low first cost.

D. SCANDIUM

This relatively scarce element can be activated in nuclear reactors; it then has an 85-day half-life and an average photon energy similar to that of cobalt 60. While it can be made in megacurie quantities quickly, its short half-life dictates a need for frequent replacement. The high cost of the elemental scandium and the lack of a developed technology make this material seem of little interest for the present application.

E. SPENT FUEL ELEMENTS

These radiation sources have the advantage of availability and demonstrated behavior in the radiation of food (Savannah River). On the other hand, fuel elements as old as three months have a low specific activity, and therefore give a low radiation dose to food. To get higher dose rates, one must use fresher fuel elements, and these require correspondingly more frequent shipment for replacement. To be most practical, the sterilizing plant should be adjacent to a high-flux nuclear reactor. If the fuel elements are too fresh, there is danger of delayed neutrons inducing radioactivity in the food. Thus, fuel elements do not appear particularly desirable for the Stockton plant.

F. GAMMA LOOPS

Gamma radiation can be produced by the circulation of a loop of sodium or indium salt through a reactor and thence through irradiated plaques. Estimate so far on a sodium loop indicate that the gamma-radiation dose rates are too low to meet the Quartermaster Corps' specifications for sterilizing food. The combination of indium salt loop and a reactor appears to be more expensive than either an accelerator, cobalt 60, or cesium 137. Some technical problems remain to be worked out in connection with the design of such a facility. The food irradiator would have to be next to the reactor.

G. GASEOUS FISSION PRODUCTS

Most of the gaseous fission products that could be collected from a fluid-fuel reactor are short-lived or emit most of their radiation in the form of beta rays rather than gammas. This has the effect of making the dose rate too low to meet the Quartermaster Corps' specifications.

H. BREMSTRAHLUNG FROM ACCELERATOR

Gamma rays or X rays can be produced with an electronic accelerator if a target of high atomic number is bombarded with electrons. Efficiency of energy utilization is low, except at very high electron-energy levels (above 10 Mev). Conversion of electron energy to electromagnetic energy at levels below 10 Mev, where induced radioactivity is minimized, is inefficient (5 to 10%). This efficiency is lowered still further by losses in absorption by the food. This course of radiation does not seem to be practical for production purposes.

APPENDIX D

ESTIMATION OF COSTS ASSOCIATED WITH IRRADIATION OF MEAT

A. INTRODUCTION

On the basis of current information, it is not possible to make precise calculations of the costs of irradiating meat. Neither is it possible to predict accurately the price at which irradiated meat would be sold to the government by commercial meat-processing plants. For the purposes of this report, however, comparisons can be made on the basis of certain assumptions.

Meat-irradiation costs have been estimated for two cases, as indicated in Table V of the main text. The first case reflects a 10-year, straight-line depreciation of the irradiating facility plus operating and maintenance costs, including labor, overhead, parts, utilities, and source replenishment. Factors not included in this case are land; working capital; selling, research, and administrative costs; and profit.

The second case shown in Table V reflects an allowance for a 20% return on the initial investment, in addition to the manufacturing-cost elements in the first case. It is currently impossible to establish the rate of return on investment that industry may see fit to require before building meat-irradiating facilities. This will depend upon an appraisal of the risks involved at that time and upon numerous other factors. In recent years the meat-packing industry has realized a return on investment of about 4-5% after taxes or 8-10% before taxes. This rate of return is lower that that of many industries. It is our opinion that companies in the meat-packing industry should strive to realize a return of at least 20% before taxes on any substantial new investment. This opinion is shared by at least one major meat-packing concern.

B. HIFI PROCESSING COSTS

The assumptions underlying the cost estimates given in Table V--exclusive of allowance for return on investment--are listed below:

1. Dose Required. It was assumed that adequate irradiation of meat requires 4.5 megarads per pound.

2. Irradiation Efficiency. The over-all irradiation efficiency was taken at 25%.

3. Operation. 300 days/yr, 16 hr/day.

4. Cobalt 60 Cost. In this study cobalt 60 was assumed to have five values, each including the cost of the cobalt itself and the cost of incapsulation. The costs used are 27-3/4¢, 50¢, 75¢, $1.00, and $2.00.

5. Transportation Cost. Our estimates assumed 1000-mile transport at 1¢ per curie-mile. (This figure was taken from the Arthur D. Little report entitled Radiation--a Tool for Industry.)

6. Installation Cost. The cost for installation was estimated from a basic cost of $10,000 per kilowatt for installation of a 30-kw cobalt source, and extrapolated on the assumption that the cost varies as the 0.6 power of the capacity.

7. Replacement Costs. The cost of replacing cobalt was determined on the assumption that 12.5% of the cobalt would be replaced annually by newly incapsulated cobalt. The cost of the new cobalt was assumed to be the same per curie as the initial cobalt cost.

8. Operating and Maintenance Cost

a. Direct Labor. Direct labor was taken at $3.50 per man-hour, assuming two full-time personnel to perform operating and health-physics functions. Since the cost of handling meat is included elsewhere in the cost data (see item 10), two people seem to be a reasonable minimum operating force for such an installation.

b. Overhead. The overhead was taken at 100% of direct labor.

c. Source Replenishment. The source replenishment is based on replacing 12.5% of the cobalt per year, which is necessary to maintain 90% of the initial strength. This 90% of the initial strength is equivalent to 100% of the rated output; that is, the initial charge was somewhat greater than required for processing.

d. Miscellaneous Parts and Utilities. Miscellaneous parts and utilities were taken at $5000 (from the Arthur D. Little report mentioned above).

9. Depreciation. Depreciation was taken over a 10-year period.

10. Nonsource Direct Labor and Overhead. A cost for nonsource direct labor and overhead, including amortization of the building and conveyor system, not directly associated with the cobalt installation, was taken at 1.4 mills. This figure is based on costs developed in the meat-packing industry.

A sample calculation of costs for a nuclide-source installation is as follows:

43.2×10^6 pounds of meat are to be processed per year, on the operating basis of 16 hr/day, 300 days/yr,

$$\frac{43.2 \times 10^6}{16 \times 300} = 9,000 \text{ pounds of meat must be processed per hour.}$$

At a dosage of 4.5 Mrad/lb, with 1 Mrad equal to 1.26 watt-hr, 1 pound of meat requires $4.5 \times 1.26 = 5.66$ watt-hr of energy.

The energy required per hour is therefore

$$\frac{9,000 \times 5.66}{0.25} = 204 \text{ kw--assuming that the over-all irradiating efficiency is 25\%.}$$

Since 68 curies of Co60 give off energy at the rate of 1 watt,

$204 \times 10^3 \times 68 = 13.9 \times 10^6$ curies of Co60 are required for 100% of required power. To compensate for Co60 decay so that the energy level will not go below 204 kw, the initial charge is of such an amount that 90% of the cobalt will give the required 204 kw. Therefore, the initial Co60 required is $\frac{13.9 \times 10^6}{0.90} = 15.5 \times 10^6$ curies.

1. Nuclide cost and preparation: $15.5 \times 10^6 \times 0.2775 = \$4,300,000$.

2. At $.01/curie-mile, shipment costs are 15.5×10^6 curies x .01 = $155,000.

3. Installation Cost:

$$\frac{15.5 \times 10^6 \text{ curies}}{68} = 227.5 \times 10^3 \text{ kw of source power (initi}$$

Using the 0.6 scaling factor, $\left(\frac{227.5}{30}\right)^{0.6} = 3.37$. Therefore the cost of installation is $3.37 \times 300,000 = \$1,010,000$.

4. The total capital investment consists of the nuclide, shipment, and installation costs.

5. Straight-line depreciation over a 10-year period results in a cost of 10% of the capital investment per year.

6. Operating and maintenance costs were determined on the assumption of 16 hours' operation per day, 300 days per year.

Direct labor costs are therefore $\$3.50 \times 2 \times 16 \times 300 = \$33,600$.

Overhead was assumed to be 100% of direct labor and is therefore also $33,600 per year.

Miscellaneous parts and utilities are assumed to cost $5,000 per year.

The source-replacement cost includes the source cost plus the shipment cost:

Co^{60} required per year: $12.5 \times 15.5 \times 10^6$ curies or 1.94×10^6 curies.

$1.94 \times 10^6 \times \$0.2775 = \$538,000$ replacement cost.

$1.94 \times 10^6 \times .01 = \$19,400$ transportation cost.

Total operating and maintenance cost is therefore $629,600.

7. The total annual cost is therefore $1,176,000.

8. The cost per pound is therefore $\frac{1,176,000}{43.2 \times 10^6} = \$.027$

9. The total cost per pound for handling and processing, including nonsource costs, is therefore $0.027 + .0014 = \$.028$.

Table D-I summarizes our calculations for two plant sizes and five levels of cobalt 60 cost. Table D-II details the operating, maintenance, and source-replacement costs used in Table D-I.

C. LINAC PROCESSING COSTS

The assumptions we made in developing the costs for the linear-accelerator installation are as follows:

1. Dose Required. 4.5 M rad/lb.

2. Operation. 300 days/yr, 16/hr/day.

3. Machine Efficiency. This is expressed as the kilowatts of power absorbed for a machine of a given size. For this study it was assumed that 7.5 kw of energy produced by a so-called 18-kw linear accelerator was absorbed.

4. Downtime. On the basis of a 16-hr operating day, a downtime of 10% was assumed. This figure was obtained from linear-accelerator manufacturers.

5. Machines. The basic LINAC used in this estimate was an 18-kw machine, and enough of these machines were used in each case to deliver sufficient dosage. When the fractional part of 7.5 kw was required, a complete 18-kw machine was assumed in the evaluation.

6. Machine Cost. The cost of the 18-kw machine required was developed as follows: The first machine cost $1.1 million dollars; the second, $770,000; the third, $660,000; the fourth, $550,000; and each machine thereafter, $495,000.

7. Transportation Cost. Shipment of these machines was based on $150 per 1000 miles shipped for each kilowatt of rated power. The distance of 1000 miles was assumed to be between the manufacturer and the point of installation. (This figure was obtained from the Arthur D. Little report on radiation.)

8. Installation Cost. The cost of installing each machine was assumed to be $77,000. This amount was held constant per machine no matter what the size of the facility, for each machine requires its own shielding and is essentially an entity in itself.

9. Operating and Maintenance Cost

a. Manpower. In determining the manpower required we assumed that one person can operate two linear accelerators and that during a shift there will be one spare operator or a supervisor.

b. Maintenance Labor. We assumed that there would be one maintenance man during each operating shift and one engineer as a maintenance supervisor for all three shifts. The operating and maintenance labor would receive $3.50 per hour; the maintenance or facilities engineer would receive $10,000 per year.

c. Overhead. Overhead was assumed to be 100% of the total labor cost.

d. Maintenance and Replacement Cost. The cost of replacing power tubes and miscellaneous parts was assumed to be $5.00 and $1.00, respectively, per machine-hour. The power consumption rate was estimated at 160 kw per machine. Power costs were assumed to be 1¢ per kilowatthour at the power factor at which the machine is operating. The power factor is believed to be approximately 0.667.

10. Depreciation. A 10-year period was taken for depreciation.

11. Nonsource Direct Labor and Overhead. A cost of 1.4 mills was assumed for the nonsource direct labor, overhead, etc.

Table D-III summarizes calculations for two plant sizes using multiple LINAC installations. Table D-IV details the operating and maintenance costs used in Table D-III.

ESTIMATION OF CERTAIN COST

Capacity	43,200,000 lb/yr, 20% kw, 13		Basis: Operat
Nuclide Unit Cost ($) (includes preparation)	.2775	.50	.
1. Nuclide Cost and Preparation	4,300,000	7,750,000	11,62
2. Shipment (1000 miles)	155,000	155,000	15
3. Installation	1,010,000	1,010,000	1,01
4. Total Capital Investment	5,465,000	8,915,000	12,78
5. Depreciation (10-yr, straight-line)	546,500	891,500	1,27
6. Operation and Maintenance			
Direct Labor	33,600	33,600	3
Overhead	33,600	33,600	3
Miscellaneous Parts and Utilities	5,000	5,000	
Source Replenishment (includes preparation and transportation)	557,400	989,400	1,47
Operation and Maintenance Subtotal	629,600	1,061,600	1,54
7. Total Annual Cost (excluding return on investment)	1,176,100	1,953,100	2,82
8. Cost per Pound of Meat Processed (excluding return on investment)	.027	.045	
9. Cost for Nonsource Direct Labor and Overhead, and Amortization of Building and Conveyer System	.0014	.0014	
10. Total Cost per Pound of Meat Processed (excluding return on investment)	.028	.046	

*Cobalt 60 required to compensate for loss of activity due to decay, based on 90% of original strength being 100% of design rating.

52249 O - 60 - pt. 1 (Face p. 624)

TABLE D-I

RTAIN COST FACTORS IN IRRADIATION OF MEAT WITH C

Basis: 4.5 M rad/lb, 25% efficiency
Operation 300 days/yr 16 hr/day

r, 204 kw, 13.9 x 10^6 curies (15.5 x 10^6 curies)*				78,500,000
.50	.75	1.00	2.00	.2775
50 000	11,620,000	15,500,000	31,000,000	7,820,000
55 000	155 000	155,000	155,000	280,000
10,000	1,010 000	1,010,000	1,010,000	1 445,000
15,000	12,785,000	16,665,000	32,165,000	9 545,000
91,500	1,278,500	1,666,500	3,216,500	954,500
33,600	33,600	33,600	33,600	33,600
33,600	33,600	33,600	33,600	33,600
5,000	5,000	5,000	5,000	5,000
89,400	1,474,400	1,959,000	3,899,400	1,005,000
61,600	1,542,100	2,031,600	3,971,600	1,077,200
53,100	2,820,600	3,698,100	7,188,100	2,031,700
.045	.065	.086	.166	.026
.0014	.0014	.0014	.0014	.0014
.046	.066	.087	.167	.027

to decay,
ting.

WITH COBALT 60

500,000 lb/yr, 371.0 kw, 25.2 x 10^6 curies, (28.0 x 10^6 curies)*

.2775	.50	.75	1.00	2.00
.820,000	14,000,000	21,000,000	28,000,000	56,000,000
280,000	280,000	280,000	280,000	280,000
445,000	1,445,000	1,445,000	1,445,000	1,445,000
545,000	15,725,000	22,725,000	29,725,000	57,725,000
954,500	1,572,500	2,272,500	2,972,500	5,772,500
33,600	33,600	33,600	33,600	33,600
33,600	33,600	33,600	33,600	33,600
5,000	5,000	5,000	5,000	5,000
.005,000	1,785,000	2,660,000	3,535,000	7,035,000
.077,200	1,857,200	2,732,200	3,607,200	7,107,200
.031,700	3,429,700	5,004,700	6,579,700	12,879,700
.026	.044	.064	.084	.164
.0014	.0014	.0014	.0014	.0014
.027	.045	.065	.085	.165

1. D

2. C

3. S

4. M

5. T

* R

Co Unit (%
0.2
0.5
0.7
1.0
2.0

TABLE D-II

ESTIMATED COST OF OPERATING AND MAINTAINING COBALT 60 INSTALLATION

	204-kw Installation ($/yr)	371-kw Installation ($/yr)
1. Direct Labor @ 3.50/man-hr	33,600	33,600
2. Overhead @ 100% of Direct Labor	33,600	33,600
3. Source Replenishment (including transportation and preparation)	*	*
4. Miscellaneous Parts and Utilities	5,000	5,000
5. Total Less (3)	72,200	72,200

* Replacement cost for Co 60 at 12.5% replacement/yr:

Co 60 Unit Cost ($)	Transportation Cost ($)	Cobalt Cost ($)	15.5×10^6 Curies[a] ($)	Transportation Cost ($)	Cobalt Cost ($)	28.0×10^6 Curies[b] ($)
0.2775	19,400	442,000	461,400	35,000	970,000	1,005,000
0.50	19,400	970,000	989,400	35,000	1,750,000	1,785,000
0.75	19,400	1,455,000	1,474,400	35,000	2,625,000	2,660,000
1.00	19,400	1,940,000	1,959,400	35,000	3,500,000	3,535,000
2.00	19,400	3,880,000	3,899,400	35,000	7,035,000	7,070,000

a. 1.94×10^6 curie replacement for 15.5×10^6 curies.

b. 3.50×10^6 curie replacement for 28.0×10^6 curies.

TABLE D-III

MACHINE INSTALLATION

Basis: 300 days/yr, 16 hr/day, 10% downtime, 7.5 kw absorbed for 18-kw machine

	Meat Processed (lb/yr)	43,200,000	78,500,000
	Power Required (absorbed)	51 kw	92.7 kw
	Units Required	7.56	13.75
	Whole Units Required	8	14
1.	Cost of Machines	5,060,000	8,030,000
2.	Shipment (1000 miles)	22,000	38,000
3.	Installation	615,000	1,080,000
4.	Total Capital Investment	5,696,000	9,148,000
5.	Depreciation (10-yr, straight-line)	569,700	914,800
6.	Operation and Maintenance	484,200	780,400
7.	Total Annual Operating Cost (excluding return on investment)	1,053,900	1,695,200
8.	Total Cost Per Pound of Meat Processed	$.0244	$.0216
9.	Nonsource Direct Labor and Overhead	.0014	.0014
10	Total Cost Per Pound of Meat Processed (excluding return on investment)	.0258	.0230

TABLE D-IV

ESTIMATED OPERATING AND MAINTENANCE COST
FOR LINEAR-ACCELERATOR INSTALLATION

Basis: 300 day/yr, 16 hr/day, 10% downtime

	Meat Processed (lb/yr)	43,200,000	78,500,000
	Power Required	51 kw	92.7 kw
	Units (18 kw) Required	8	14
	Operators per shift	5	8
1.	Direct Labor @ 3.50/man-hr	84,000	134,000
2.	Maintenance Labor	26,800	26,800
3.	Total Labor	110,800	160,800
4.	Overhead @ 100% of Direct Labor	110,800	160,800
5.	Power Source Replacement @ $5/hr/machine	173,000	302,000
6.	Miscellaneous Parts and Utilities	89,600	156,800
7.	Total Annual Operating and Maintenance Cost	484,200	780,400

Appendix 5

DRAFT COPY
of the
ABSTRACT, RECOMMENDATIONS and SUMMARY
of
AN EVALUATION OF THE TECHNICAL, ECONOMIC AND PRACTICAL FEASIBILITY OF RADIATION PRESERVATION OF FISH

by

B. E. PROCTOR, S. A. GOLDBLITH,
J. T. R. NICKERSON and D. F. FARKAS

Department of Food Technology
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

Performed under
Task VI and Contract Number AT(30-1)-2329
with the
UNITED STATES ATOMIC ENERGY COMMISSION

ABSTRACT AND RECOMMENDATIONS

Based on exploratory studies conducted over the last six years on the radiation-preservation of various marine species, it is apparent that low dose substerilization-radiation treatment of certain selected sea foods can provide advantages for the procurer, processor, distributor and consumer of edible marine products. In fact, it is probable that marine products will be among the first to be processed by irradiation substerilization. It is therefore recommended that a comprehensive, synchronized government-industry program be initiated for the development of substerilized, radiation processed marine products.

If such a method of processing were developed to the point of successful commercial application, it is considered that nutritious marine foods could be made available to consumers presently not easy to supply; fresh-type marine products could be provided to consumers who are presently able to obtain only canned, frozen or dried products of this kind; and market prices of marine products, presently subject to fluctuations due to overabundances and paucities, would tend to be stabilized.

The reasons for emphasizing a radiation program for marine products are the following:

(a) Fish and fishery products, held under refrigeration at temperatures between 32° and 40°F, normally spoil because of the growth of cold-adapted or psychrophilic bacteria such as Pseudomonas fluorescens, P. fragi, and P. putrefaciens. These types of bacteria are destroyed by relatively low doses of ionizing radiations. Hence, a considerable extension of the storage life of marine products at 32° to 40°F may be attained with relatively low dosage irradiation treatment.

(b) The application of irradiation to fishery products would not require the development of new preparation methods and manufacturing techniques, presently not used in processing these foods for shipment as the fresh, refrigerated product.

(c) Commercial production installations presently set up to process fish for handling as the fresh, refrigerated or frozen product would require a minimum of modifications for adaption to radiation processing.

(d) The extension of the refrigerated storage life of marine products by radiation substerilization would create a more favorable supply situation, since irradiated refrigerated fishery products may be stored for some time before shipment, thus providing greater flexibility in matching supply and demand.

(e) Products so treated, while possessing a shelf life of up to 30 days or longer at 35°F, would be fresh in nature in contrast to the normal frozen products.

(f) These irradiated, substerilized products would have a unique "heat and eat" character.

(g) These products would not require thawing before use.

(h) Because of the extended refrigerated shelf life at 35°F, irradiated marine products could be packed at their source and shipped to any point in the United States by the most economical means of refrigerated transportation. Inland cities, now receiving only frozen products of this kind, would thus be able to share the economic and esthetic advantages provided by the fresh product.

(i) Extension of refrigerated shelf life by irradiation would allow the establishment of brand identity and an increase in size of fish processing establishments, due to increases in the use of filleted or processed fresh fish and the establishment of a more favorable supply situation.

(j) Fishery products, which have been treated with irradiation for purposes of extending storage life at refrigerator temperatures above freezing, more nearly resemble fresh refrigerated or frozen products of the same kind.

(k) At present, fresh refrigerated fishery products can be shipped for only limited distances because of their extreme perishability.

(l) It would be monetarily less expensive to process marine products by irradiating and refrigerating than by freezing because of the comparatively low cost of substerilization-radiation treatment and the relatively high cost of freezing, transportation in the frozen state, costs of frozen storage and movement of frozen products in and out of storage.

(m) Examples of marine species which might be suitable in the refrigerated, irradiation substerilized state are: flounder, halibut, cooked shrimp and other crustacean products, scallops, ocean perch, mackerel, finnan haddie and others.

It is recommended that the government-industry irradiation program be designed to include the following:

A research and development prospectus to determine:

1. Those marine species (presently not evaluated) that may be suitable for commercial irradiation processing.
2. More specifically the degree of extension of storage life at 32° to 40°F that may be attained by treatment of suitable marine species with ionizing radiations at dosages between 50,000 and 750,000 rad.
3. The nutritional value, including vitamin and amino acid content of the cooked and uncooked proteins and vitamin content of fats, of marine species treated at radiation dosages between 50,000 and 750,000 rad, as compared to the cooked and uncooked protein and fats of canned and frozen fish of the same species, as a function of dose and of length of storage.
4. The organoleptic and consumer acceptance of suitable marine species treated by substerilizing irradiation dosages.
5. Pertinent processing requirements, including packaging materials, packaging conditions and storage temperature limitations.
6. Marketing conditions under which irradiation substerilized marine products can provide the greatest advantages to the fishing industries and to the consumer.
7. The wholesomeness of substerilized irradiated marine products under actual conditions of processing. For example such a study might be conducted on a suitable species, such as ocean perch at a substerilizing dose of 0.5 megarad (actual conditions of use). Human feeding studies should also be carried out with this material.

   Such a study would be complimentary to investigations already proceeding under the supervision of the U. S. Army.
8. To provide the necessary facilities for carrying out the program. Such facilities would include:

   (a) Two interim radiation facilities, 10,000 to 50,000 curies in size to be provided as soon as possible, one of these

sources to be located within a two-hour driving distance of Boston, Mass., the other to be located near Seattle, Washington. These facilities would be convenient for investigations which would be carried out by the Fish and Wildlife Service Laboratories.

(b) A pilot plant marine products irradiator. This pilot plant should be located within a two-hour driving distance of Boston, Mass., and should be available within two years after the program has been initiated.

Relative to the proposed government-industry program for the development of irradiation substerilized marine products, it is considered that the provision of suitable radiation facilities, the nutritional studies and the evaluation of the wholesomeness of irradiation substerilized marine products would be entirely a government responsibility. As the program developed, industry would be expected to carry out additional tests and, at least in part, determine further pertinent information. During the transition from government to industry, irradiation time could be provided on a "no cost" basis on condition that information determined under such circumstances were made available to interested groups.

SUMMARY

1. GENERAL CONCLUSIONS DRAWN FROM INSPECTION OF AVAILABLE PERTINENT LITERATURE ON THE SUB-STERILIZATION OF MARINE PRODUCTS BY RADIATION

The following conclusions are based on information from the various papers in the literature reviewed in this report:

1. When marine products are irradiated at sterilizing doses (4 to 6 x 10^6 rad), these products undergo changes in flavor, odor, texture and color. At levels required for the extension of storage life at 32° to 40°F, such changes are minimized and in some cases undetectable due to the relatively low dosages required. Dose levels as low as 250,000 rad may provide an extension of storage life at 32° to 40°F of 5 days or longer. Even this short extension of storage life could be of tremendous advantage in the marketing of fish as a fresh-type product since it would provide the extra storage time necessary for the distribution of such commodities to inland cities.

2. Radiation treatment at low dose levels will allow routine handling of fish as a semi-perishable product with a shelf life of up to 21 - 30 days or more. Movement of stocks can be optimized within this period, and some inventories can be built up to handle peak demand such as for Fridays or special holidays. One important aspect of radiation preservation is that brand allegiance and quality aspects of fresh fish can be established through a good marketing and distribution program. Heretofore, this advantage has not been possible with fresh fish.

The prime objective of the radiation preservation of marine products is to provide for inland markets, at a favorable price, a better quality product than that now available. The technical fulfillment of this objective will create a tremendous new market for fresh fish, by providing sales outlets in distant high density population areas in the Midwest.

The effect of the demand increase should be the stabilization of the production of fish by increasing the magnitude of the operation, as a result of

the increase in the demand for fish. The results of a greater and more stable demand should be a tendency towards a stabilization of prices at an average lower value, but at a greater total dollar value due to a much greater volume of sales.

3. At dose levels below 0.5 megarad, spoilage is usually caused by bacterial growth. The microbes involved are those not usually associated with classical fish spoilage. Standard tests for fish spoilage may not be useful in the detection of quality loss in this case.

4. At dose levels above 0.5 megarad, microbial spoilage of refrigerated marine products is of minor importance. Products fail due to chemical and/or enzymatic changes, the pattern being characteristic of the species treated. This spoilage includes: trimethylamine formation (non-microbial), proteolysis, rancidification of fats and the possible formation of metabolic end products.

5. Because little work on radiation preservation of fishery products has been done without a freezing step, and since fresh fishery products have not always been available at the time of irradiation, results reported in the literature to date cannot be applied without reservation. No large scale studies have been carried out.

6. If economic and marketing factors are to be considered, the problem of proper packaging for irradiated marine products has not been resolved. Most work has been done on products packed under vacuum in hermetically sealed containers. In general this package gave the best results.

7. The storage life of marine products at temperatures below 40°F is extended by substerilization treatment, but the initial quality of irradiated fish of certain species may be less than that of fresh fish. However, with certain other species irradiated at substerilization levels, the fresh and the treated product may be indistinguishable from one another.

8. The type of cookery used to prepare irradiated fish has a marked effect on its acceptability. Frying tends to mask organoleptic changes due to irradiation. Frying and broiling are the preferred methods of fish cookery. Proper cookery of irradiated marine products should be emphasized either by advertising or by label information.

9. Precooking of fish fillets or shellfish will aid in prolonging refrigerated shelf life. However, the resultant product is not fresh fish or shellfish.

Certain products, now precooked and frozen, can be precooked and irradiated; these include fish sticks, breaded fish steaks and fillets, oysters and scallops, parboiled shrimp and lobster, and smoked items such as kippered herring and finnan haddie. The above items will require individual evaluation but in general smoked or pre-processed marine products respond well to sub-sterilizing doses of gamma radiation.

10. According to the literature, the following species appear to be suitable for substerilization by irradiation treatment and refrigerated storage at 32° - 40°F:

Fillets: Haddock (smoked), flounder (blackback), butterfish, mackerel, lemon sole, halibut, petrale sole, ocean perch, tuna, Pacific cod.

Shellfish: Shrimp, lobster, crab, oysters, shucked clams.

Specialty items: Acceptability of specialty items depends on the formulation of the product and the species involved. The use of breading, smoking or pickling in conjunction with irradiation may yield a more acceptable product.

11. Radiation-induced changes in texture, color and drip are slight at dose levels below 1 megarad. There is a general bleaching of pigment, especially in salmon. However, with certain species such as pollock, bleaching is desirable. Irradiation may produce an odor of its own but the irradiation treatment delays the development of a "decomposing fish" odor which is due to the accumulation of trimethylamine in some species, and which is, of course, undesirable.

12. Enzymatic activity in fresh fillets or in shellfish products is variable and depends on the species. For products stored below 40°F, for less than one month, enzymatic spoilage should not be a problem with most species. With non-oily species of fish, enzymatic activity in fillets does not affect storage life at temperatures below 40°F.

13. Results on vitamin losses at sterilization doses are similar to those obtained with heat treatment applied at the "commercial sterilization" level. Since all investigations of the nutritive quality of irradiated marine products have been carried out with fish or shellfish treated at the relatively high sterilization dose level, it would appear that nutritive changes in sub-

sterilized, refrigerated marine products may be of lesser importance. Investigations should be made of the nutritive quality of irradiation-substerilized, refrigerated marine products. In addition, feeding tests to laboratory animals over a 2-year period with these sub-sterilized fishery products should be conducted.

2. RESEARCH AND DEVELOPMENT WORK NECESSARY TO INTRODUCE ACCEPTABLE RADIATION-PRESERVED FISH PRODUCTS INTO THE U.S. ECONOMY

In order to introduce radiation-preserved fishery products into the economy of the United States, the following steps are recommended:

A. That a government-industry program be initiated to resolve certain questions and to obtain certain information presently not available. This program should include:

1. Research to determine those marine species (presently not evaluated) which might be suitable for irradiation-substerilization processing. It is possible that an investigation of this kind would provide for a much greater commercial application of radiation preservation than would be possible through that information now at hand.
2. An investigation to fix the limits of storage time at temperatures between 32° and 40°F which may be applied to marine species after radiation processing at dosages between 50,000 and 750,000 rad. Data of this kind would provide for the setting up of processing technology for the handling of products preserved in this manner.
3. Investigations to determine the amino acid content and the vitamin content of marine products treated at dosages between 50,000 and 750,000 rads as compared to the amino acid and vitamin content of canned and frozen fish. This research should include animal assays as well as "in vitro" chemical tests, and should

52249 O—60—pt. 1——41

be carried out on the cooked and uncooked portions of all foods examined. Tests should also be made on all foods before and after storage at temperatures ordinarily used for the particular product involved. It is considered that information of this kind is necessary for reasons of public health and for the elucidation of the processor, retailer and consumer.

4. An investigation of the acceptance of radiation-treated marine species at dosages between 50,000 and 750,000 rad. Both flavor panel and consumer-type tests on several species of different marine groups (fish, crustaceans and mollusks) should be included in this work. Information of this kind would tend to fix the limits of radiation treatment, and therefore the storage time which could be applied to any particular species.
5. Research to determine what packaging materials and packaging conditions for radiation-substerilized marine products provide the best results from the standpoint of quality of product and extension of storage life at 32° to 40°F. This work should include an investigation of non-fatty, moderately-fatty and fatty fish, crustaceans and mollusks. Various films as well as metal containers should be evaluated, and products should be evaluated after packaging in air, under vacuum, etc. Information of this kind is necessary for the successful radiation processing of marine products. It is also apparent that if radiation-processed marine products could be handled in bulk (30 to 50 pound containers) as are fresh unirradiated fillets (the latter may be shipped for only short distances because of their extreme perishability), this method of processing would provide extreme economic advantages.
6. An inquiry to determine those conditions under which radiation-processed marine products should be marketed in order to provide the greatest overall benefits to the fishing industry, procurer, processor, distributor and to the consumer. It is recommended that such an investigation be carried out by the Fish and Wildlife Service of the Department of the Interior.

7. A study, complementary to the program presently being carried out by the Department of the Army to determine the wholesomeness of radiation-substerilized marine products. At least one species, treated under the actual conditions of use (a dosage which would be employed commercially, approximately 0.5 megarad) should be fed to laboratory animals over an extended period to determine any untoward effects. In addition, human feeding studies should be carried out with these treated products. It is considered that wholesomeness studies should be entirely a government responsibility.

B. The government should provide facilities for research and development. These facilities would include:

I. Interim Radiation Sources

Two interim radiation sources of approximately 10,000 to 50,000 curies in size. These sources should be provided as soon as possible in order to facilitate the compilation of information necessary for the successful commercial application of radiation processing.

Because of the availability of suitable marine species as well as the proximity of suitable laboratories and trained laboratory personnel in these areas, it is recommended that one of these sources be located at a point within a two-hour driving distance of Boston, Mass., and the other be located in or near Seattle, Washington.

II. Pilot Plant Marine Products Irradiator

Within two years after the initiation of the government-industry program, a pilot plant marine products irradiator should be completed. It is recommended that this irradiation facility be located at a point within a two-hour driving distance of Boston, Mass. Location of the pilot plant near the source of the marine species to be processed, would eliminate such undesirable factors as the necessity to freeze products to be irradiated for purposes of shipment to and from the radiation source.

It is considered that the government should be responsible for funds for supplying radiation sources and for initiating research to

determine such things as wholesomeness. Eventually industry should participate in the research and development program. During the transition from government to industry, irradiation time could be provided without cost. Under such circumstances, the results of such research should become available to all interested groups.

3. SUMMARY OF ECONOMIC CONSIDERATIONS

Radiation preservation of marine products by substerilization will not involve the development of any new pre-processing or preparation methods. The substerilization of marine products by radiation treatment offers unique advantages. These are:

1. The product, while possessing a shelf life of up to 30 days at 35°F, is fresh in nature.
2. The product has a unique "heat and eat" character.
3. The product does not require thawing before use.
4. Because of the extended refrigerated shelf life at 35°F, irradiated marine products may be packed at their source and shipped to any point in the United States by the most economical means of refrigerated transportation. Inland cities now receiving only frozen products of this kind would thus be able to participate in the economic and esthetic advantages provided by the fresh product.
5. Extension of refrigerated shelf life by irradiation will allow the establishment of brand identity and an increase in size of fish processing establishments due to increase in the use of filleted or processed fresh fish and a more favorable supply situation. The latter results from the fact that irradiated fresh fishery products may be stored for some period of time before shipment, thus making possible a more favorable matching of supply with demand.

6. Fishery products which have been treated with irradiation to extend storage life at 32° to 40°F, more nearly resemble fresh refrigerated or frozen products of the same kind.
7. At present, fresh refrigerated marine products can be shipped for only limited distances because of their extreme perishability.
8. It would be economically more costly to process marine products by freezing than to process them by irradiation at substerilization doses and refrigeration, because of the comparatively low cost of substerilization treatment and the relatively high cost of freezing, transportation in the frozen state, freezer storage costs and movement of frozen products in and out of storage.
9. On 30 to 50 pound bulk packaged radiation-preserved product, it should be possible to save as much as 0.5 to 1.0 cent per pound on packaging material alone, as compared to the cost of packaging frozen products of the same kind. This estimate does not include inherent savings based on the fact that labor costs and equipment costs for retail unit packaging are much greater than for bulk packaging.

4. SUMMARY OF PACKAGING REQUIREMENTS

Packaging requirements for retail and wholesale packaging of irradiated fishery products can be satisfied in accordance with the following:

I. A Package to hold 30 to 50 pounds of Product for Radiation Processing

Such product would not be individually wrapped as retail units. This package would have to be of such a nature that it would preclude the entrance of microorganisms. The bulk-type metal container presently used for shipping fresh-refrigerated fish fillets (used for only short-distance shipping) might be suitable for this purpose. It is also conceivable that a less expensive, plastic impregnated paperboard carton could be developed for radiation-processed bulk packs.

II. A Consumer Size Package holding 1 pound of Product

This package could be made in the form of a polyethylene-laminated cellophane bag to be vacuum sealed and overwrapped with a waxed bending board carton. Five or ten of these packages would be overwrapped in a waterproof fiberboard carton for irradiation and handling during shipment. The proposed package is very similar to that used for vacuum packed meat products now on the market.

III. A Wholesale Size Package to hold 5 or 10 pounds of Product in a Heavy-Walled Polyethylene or Polyethylene-Coated Cellophane Bag

Overwrapping with a waterproof fiberboard carton of the same size as the overwrap for the retail size package would facilitate handling. It is expected that two cartons could be irradiated simultaneously to form a block.

Package dimensions should be set to optimize source efficiency and are only limited by product dimensions and net weight specifications.

Commercial Storage Requirements

It would be necessary to store substerilized irradiated marine products as close to 33°F as possible. While excursions above this temperature are expected during distribution, proper education and precautions should be taken to insure optimum storage conditions. The maximum allowable storage temperature is to be set at 40°F.

5. SELECTION OF RADIATION SOURCES AND PREFERRED GEOMETRY

Part B of the main report shows a possible design concept for a marine products pilot plant irradiator. Cobalt-60 is recommended as the isotope of choice in the above irradiator because of:

1. Relatively high gamma energy (average, 1.25 MEV), and total gamma energy per disintegration (2.5 MEV).
2. Reasonable ease of source fabrication, transport and protection.
3. Inherent safety of encapsulated cobalt metal.
4. Simplicity of use in operation.
5. Absence of induced radioactivity.
6. Present and future availability.
7. Ease of dosimetric measurements and source monitoring.
8. Short range expected use of the source, i.e., to demonstrate feasibility over a limited time as a pilot-plant operation.
9. Extensive knowledge concerning this isotope is already available.

Packages of marine products would be in the form of slabs, or blocks. While it is beyond the scope of this project to give a detailed source design, it is recommended that the efficiency of the irradiator be optimized through the selection of suitable package dimensions. All equipment should be designed to be automatic in operation and as safe and foolproof as possible.

6. OTHER METHODS OF FISHERY PRODUCT PRESERVATION

It should be possible to open up additional markets for marine fishery products by preservation with radiation substerilization and refrigeration. At this writing, antibiotic treatment has not been approved for processed fishery products and treatment of such species with antibiotics results only in a limited extension of storage life. Competition from freeze-dried products is not seen to be important due to economic considerations, lack of information concerning freeze-dried fishery products at the present time and lack of convenience characteristics of the freeze-dried product.

7. SUMMARY OF INFORMATION AND RECOMMENDATIONS ON WHOLESOMENESS

At present the Food and Drug Administration will not allow the sale of foods treated by ionizing radiation to extend storage life.

The Quartermaster Corps has a program under way, under the technical control of the Surgeon General, to obtain clearance of 21 foods sterilized by ionizing radiation. These foods include the following marine products: tuna, shrimp and cod fish.

Results of this QMC-SGO program may not be available in complete form for as long as two years. When this program is complete, the Food and Drug Administration will have data enabling them to judge the safety of the process based on the experimental results obtained.

To date there has been no indication of toxicity or induced radioactivity in any of the foods tested in the wholesomeness program. Therefore it is expected, based on present findings and barring any untoward results, that the process should be approved by the Food and Drug Administration.

It is recommended that the AEC support a wholesomeness test involving the feeding of one species of substerilized irradiated fish to rats over a period of two years. It is further recommended that acceptability tests, involving feeding to humans, using foods treated under actual processing conditions, should be included with this investigation.

It is further recommended that the AEC support a program to thoroughly investigate the nutritional quality of radiation substerilized marine products.

8. ESTIMATED PHASING IN TERMS OF TIME FOR RESEARCH AND DEVELOPMENT PROGRAM AND PILOT PLANT CONSTRUCTION

Successful demonstration of the commercial feasibility of marine products preservation by irradiation will involve the following phases:

1. Immediate construction of two interim radiation sources, 10,000 to 50,000 curies in size.

2. Design and construction of a marine products pilot plant irradiator.
3. A research and development program to be initiated prior to construction of the pilot plant, and to be carried on concurrently with the pilot plant operation.
4. Overall project administration.

It is estimated that the various phases would involve the following in terms of time:

A. Design and construction of two interim radiation sources. These are to be completed within 9 months after initiation of the program.

B. Design and construction of pilot plant irradiator. To be completed within 2 years after initiation of the program.

C. Accurate determination of storage life at 32° to 40°F of marine products processed by radiation substerilization treatment. To be completed within two years after initiation of the program.

D. Nutritional value of radiation processed marine products. A period of from 3 to 5 years may be required.

E. Evaluation of the organoleptic and consumer acceptance of radiation processed marine products. A period of 3 years may be required.

F. Determination of the pertinent processing parameters (packaging materials and conditions). A period of 2 years may be needed.

G. Evaluation of marketing conditions which should be applied to radiation processed marine products. A period of 1 year should suffice.

H. Evaluation of the wholesomeness of radiation processed marine products. A period of 2 years of feeding tests will be needed with an additional 6 months for evaluation.

Appendix 6

[Reprinted from FOOD RESEARCH, 1955, Vol. 20, No. 3, Pages 193-214]

GROWTH, REPRODUCTION, SURVIVAL AND HISTOPATHOLOGY OF RATS FED BEEF IRRADIATED WITH ELECTRONS

C. E. POLING, W. D. WARNER, F. R. HUMBURG
E. F. REBER*, W. M. URBAIN, AND E. E. RICE
Research Laboratories, Swift & Company, Chicago, Illinois

(Manuscript received February 25, 1955)

The retarding or control of microbial growth in foods is commonly accomplished by refrigeration, cooking, canning, salting, or drying. For many purposes these methods are satisfactory, but for others they leave much to be desired. Recent demonstrations that ionizing radiations will destroy or at least prevent the multiplication of bacteria have stimulated interest in the use of this form of radiant energy in the preservation of foods.

Beams of relatively fast-moving electrons, more commonly known as cathode or beta rays, are effective for this purpose. In accomplishing this bactericidal action, the rays cause no significant temperature rise and leave no residual radioactvity. The procedure may be considered as a *cold* sterilization process. Also, beta rays penetrate materials and consequently, unlike ultraviolet light, exert bactericidal action throughout the food.

The use of electron beams in treating food for the purpose of controlling the microbial growth offers many possibilities. Most of these center about the fact that the process induces no significant rise in temperature. Thus one may obtain, for example, a piece of raw meat which is completely sterile. Many, if not all, of the enzymes may remain active. Investigations have shown that under certain conditions the treatment of meat with electrons produces desirable results.

This report describes experiments made with rats to determine the effect of beta irradiation upon the wholesomeness of beef as a food. It includes methods of irradiation, observations of the relative growth, food efficiencies, reproductive capacities, adult survivals, and histopathological abnormalities of rats fed diets containing irradiated or non-irradiated beef.

PROCEDURE

Irradiation of beef. A definite amount of radiant energy is required to inactivate bacteria. It is generally considered that approximately two million roentgen-equivalents-physical (rep) *(18)* are a sterilizing dose sufficient to destroy even the most resistant forms of food spoilage bacteria, including spores. For this experiment this level of treatment was chosen since it approximated the most likely maximum commercial application dose. Further, as will be seen below, provision of a minimum dose of 2×10^6 rep inherently included some overdosage, making the average dose higher and thereby allowing a safety factor not much different from that to be expected in commercial use. Levels of treatment above 2×10^6 rep were believed to be unrealistic and possibly misleading for normal meat products.

Due to the absorption characteristics of cathode rays and to the distribution patterns of the generators used *(7)* it was not possible to obtain a uniform dose throughout

* Present address: College of Veterinary Medicine, University of Illinois, Urbana, Illinois.

the portion being irradiated. The non-uniformity was minimized by controlling the size and shape of the portion being treated and by irradiating both top and bottom surfaces. In order to maintain definite physical dimensions, all samples were kept frozen during irradiation.

In these experiments the meat was irradiated so that no portion received less than approximately 2×10^6 rep. This caused the average to be somewhat higher depending on the equipment used. Approximately half of the irradiated meat used in this experiment was treated with a Capacitron cathode ray source and the rest was treated with a resonant transformer type source.

The Capacitron *(10)* periodically emitted micro-second bursts of electrons with energies of about two million volts. Calibration of the beam output energy was made calorimetrically. These electrons form a circular pattern of greatest intensity at the center. In order to permit uniform treatment the meat was formed into concentric rings with a thickness of 1.27 cm. The first of these was a disc 14 cm. in diameter; succeeding rings had inside and outside diameters as follows: 15.3 to 20.3 cm.; 21.6 to 26.7 cm.; and 27.9 to 35.6 cm. Each of these was held in the electron pattern until a calculated number of bursts had been applied. The dose within any ring varied from a minimum of 1.9×10^6 rep to a maximum of 6.3×10^6 rep, and averaged 3.7×10^6 rep on the basis of 1 rep = 93 ergs per g.

The General Electric resonant transformer type of source was used to treat the balance of the meat. This unit emits a relatively continuous beam of electrons at an accelerating voltage of 800,000 peak volts. The calibration of the beam output energy was made with an ionization chamber *(13)*.

Portions of frozen meat ($6.35 \times 6.35 \times 0.32$ cm.) were passed continuously on a conveyor system through the electron beam at a distance of 10 cm. from the tube window. The conveyor speeds and beam current were adjusted so that the dose was a maximum of 3.0×10^6 rep and a minimum of 2.2×10^6 rep. The average was 2.7×10^6 rep on the same basis as above.

Except for the differences noted for the range of dose maxima and averages, the samples treated with either the Capacitron or the resonant transformer received identical treatments, and no differences between the meat irradiated by the 2 units are assumed. The variation in dose maximum and average is not regarded as significant, the essential identity of the minimum dose being the governing consideration.

Animal feeding experiment. Before beginning the long-term animal feeding experiment, feeding tests had been conducted to provide preliminary information considered desirable. The results of these tests indicated: (a) that rats would thrive for several weeks on diets in which meat supplied as much as 89% of the solids, (b) that in such diets the type of carbohydrate was not critical, (c) that rats would eat readily diets containing high levels of irradiated beef, and (d) that irradiation with 5×10^6 rep decreased the nutritional quality for growth of beef protein only slightly and less than retorting according to a regular commercial processing schedule for canning.

For the long-term feeding experiment, weanling rats of the Holtzman strain were procured and conditioned for 3 days on a stock diet. These were divided into two groups of 80 rats each (40 of each sex) with comparable average starting weights and distribution of weights. The rats were caged individually in $17.8 \times 25.4 \times 17.8$ cm. cages except during reproduction and housed in an air-conditioned animal room maintained at $27° \pm 1°$ and 40-50% relative humidity. Those animals which became very large (over 500 g.) were transferred to $41.9 \times 25.4 \times 17.8$ cm. cages.

Diets intended to provide all known nutritional requirements of the rat were formulated for both groups. Excluding the water contained in the meat, the percentage formulation of the diets was: beef solids, 45; corn starch, 43; salt mixture,[b] 4; liver concentrate (Wilson's N.F.), 2; Ruffex,[c] 2; vitamin A & D oil (2250 U.S.P. units of A, 300 I.C.U. of D_3), 1; wheat germ oil, 1; yeast (Annheuser-Busch Type 300), 1;

[b] The salt mixture was a phosphorus free, high calcium modification of that of Jones and Foster *(11)*. This modification was considered desirable because of the large contribution of available phosphorus by the beef hamburger. In the mixture used 216.0 g. of $CaCO_3$ and 600.6 g. of $KHCO_3$ replaced 816.6 g. of KH_2PO_4.

[c] Ruffex is ground rice hulls processed to serve as non-nutritive roughage.

TABLE 1

Proximate analyses of diets

	Control		Experimental	
	As fed	Dry (calc.)	As fed	Dry (calc.)
	%	%	%	%
Moisture	42.0	.....	41.6	.....
Solids	58.0	100.0	58.4	100.0
Protein (N × 6.25)	11.6	20.0	12.1	20.7
Fat	17.2	29.6	16.7	28.6
Ash	2.68	4.62	2.80	4.79
Calcium	0.48	0.83	0.47	0.80
Phosphorus	0.31	0.53	0.32	0.55
Ca/P	1.55	.....	1.46	.....

[1] Averages of seven separate preparations of each diet.

and orthophosphoric acid (85% H_3PO_4), 1. During the 11th week and for the duration of the experiment 1 mg. per cent of 2 methyl naphthoquinone (Menadione) was added to both diets, although there is little, if any, evidence that the rat requires a dietary source of this vitamin.

Diets fed the experimental and control groups were identical except that beef hamburger irradiated as described above was used in the experimental diet while unirradiated hamburger was used in the control diet. The raw beef hamburger used was a commercial product[d] untreated except for grinding, freezing, and storage at −18° until needed for irradiation or diet preparation.

In preparing the diets, all ingredients except the beef were premixed in quantities sufficient for 2 to 3 weeks feeding and stored at 5-10° until used. This premix was then mixed with either raw or irradiated hamburger in the ratio of 112 g. hamburger (equivalent to 45 g. beef solids) to 55 g. premix. Fresh diets were made weekly for the first 10 months; after this they were prepared at intervals of 10 to 12 days. The diets were divided into portions sufficient for one day's feeding, wrapped in heavy wax paper, frozen quickly, and stored at about −18° until used. The diets were thawed just before feeding (with the exception of week-ends and holidays) and were fed daily *ad libitum*.

The beef hamburger comprised about two-thirds of each diet as fed and provided 60-65% of the total calories. The essential similarity of the diets in content of major nutrients is indicated in Table 1 by the average proximate analysis of 7 batches of each diet.

The original two groups of 80 rats each (hereafter referred to as the parent generation) were maintained on their respective diets for 2 years without change in formulation of the diets or any supplementation except the addition of vitamin K, as noted above. During this period, comparisons were made of: growth and adult body size (weekly weight records), food consumption,[e] reproduction, mortality, hematology, tumors, and gross and histopathology on representative animals at 3, 6, 12, 18 and 24 months (end of the experiment). General observations were made on a daily basis, with a critical examination once weekly, of the grossly apparent state of health of each animal. Apparent deviations from a normal state, even if slight, were recorded chronologically for each animal. The data, wherever feasible, were subjected to statistical

[d] Swift & Company's Arrow S brand.

[e] In general complete individual food records were kept meticulously for all animals on a weekly basis by calculating from the weight of wet diet offered the equivalent weight of dry solids and subtracting from this weight the actual weight of dry solids returned uneaten. All uneaten and scattered food was collected (daily except week-ends and holidays) in individual containers for each animal and dried weekly at about 116° before weighing. Although food records were kept during the reproduction phase of the experiment, it was impractical to keep individual records for each animal at this time because of the necessity for multiple occupancy caging.

analysis and throughout the paper differences between groups have been described with the conventional usage of significant ($P < 0.05$) and highly significant ($P < 0.01$).

The original animals were mated for the production of first and second litters of first generation offspring. The first litter weanlings were discarded, and representative second litter weanlings were saved for growth and production of first and second litters of second generation offspring. This same procedure was repeated with the second generation to obtain first and second litters of third generation offspring. The first litter third generation weanlings were discarded and the second litter weanlings were sacrificed for histopathological examination of representative animals.

Although the plan outlined above was followed in general, the results as they were obtained necessitated some modification in the details of the procedure which will be explained later in reporting the results.

Growth and Adult Weights

Figure 1 shows that the growth of animals fed both control and experimental diets was exceptionally good in the 3 generations which were carried through the 9-week initial growth period. The similarity in the growth response of all rats fed the control and experimental diets is evident, as is the fact that there was no cumulative decline in growth for each succeeding generation. The experimental males gained slightly less in each generation than the control males; the difference in gains was not significaut ($P < 0.07$) in the parent generation and the second generation but was significant in the first generation. For the females, growth on the experimental diet did not differ significantly from that on the control in any generation.

The parent generation rats were continued on the experiment to complete a 2-year period. The first and second generations were continued long enough to permit each female a reasonable opportunity to bear 2 litters (30 weeks for the males and 35 weeks for the females). During the 30-week period the male animals, in particular, developed to a very large size for both groups in all generations. The parent generation males, especially the controls, eventually became exceptionally large during the 2-year period and probably could best be described as obese (four actually attained maximum weights over 800 g.; one of these was over 900). The parent generation females, although well nourished, did not tend to store fat to an excessive extent until after the second litters were weaned when some of them likewise became quite obese.

The data in Table 2 demonstrate that the experimental males were very large animals although their adult weights progressively fell below those of the control males in all generations. The differences were larger and were significant after 14 weeks in the parent and first generation, but never became significant for the second generation. The largest difference occurred in the parent generation and was highly significant after 30 weeks. Although the difference continued to increase progressively through 78 weeks and remained significant for the parent generation, the survivors after 104 weeks (end of the experiment) showed a much smaller difference, which was not significant.

The adult weights of the females in each group were difficult to compare during the period 10 to 35 weeks because of the effects of pregnancy and lactation upon weight. However, the parent generation experimental females were not significantly smaller than the control females until the 104th week. The experimental females were not significantly smaller than the control females in either the first or second generations when discarded at 35 weeks.

When comparing one generation with the following one, the average weights at 14 and 30 weeks on experiment for both the first and second generation animals usually equaled and often exceeded those of the parent generation. This was true for both sexes within both groups. If the assumption is made that a direct comparison of one generation with another is valid, then the following comparisons can be made, the first group weighing more than the second:

1. Differences highly significant at times indicated.
   a. Control first generation males: control parent generation males (30 weeks).
   b. Experimental second generation males: experimental parent generation males (14 weeks).

c. Experimental second generation males: experimental first generation males (14 weeks).

2. Differences significant at times indicated.
   a. Control second generation males: control parent generation males (14 weeks).
   b. Experimental first generation males: experimental parent generation males (30 weeks).
   c. Experimental second generation males: experimental parent generation males (30 weeks).
   d. Control first generation females: control parent generation females (14 weeks).
   e. Control first generation females: control second generation females (14 weeks).

In connection with the reproduction phase of the experiment, about one half of the animals of each sex in each dietary group of the first generation were given an oral supplement of 10 mg. DL alpha tocopherol five times weekly beginning with the

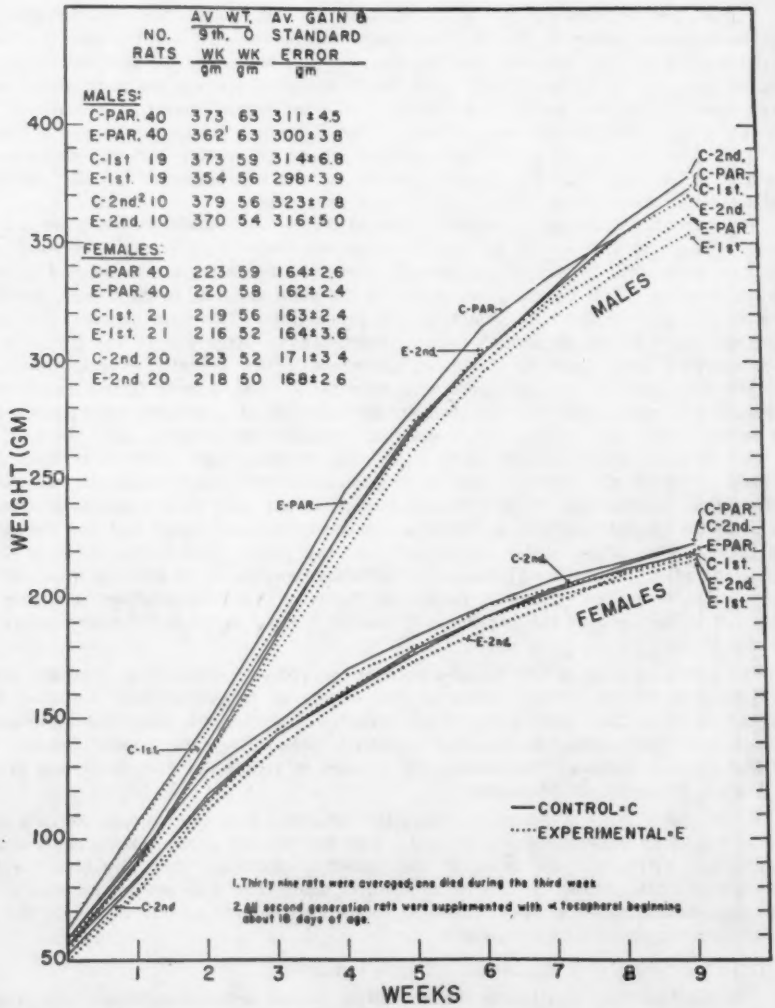


Figure 1. Nine week growth. For parent, first and second generation rats fed diets containing raw (control) or irradiated (experimental) beef hamburger.

TABLE 2

Average adult weights of 3 successive generations fed diets containing raw or irradiated beef hamburger[1]

End of Week	Males—Weights in grams						Females—Weights in grams					
	Parent		First[2]		Second[3]		Parent		First[2]		Second[3]	
	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl
10	380[4](40)	367[4](39)	386(19)	366(19)	395(10)	384(10)	224[4](40)	222[4](40)	225(21)	225(21)	229(20)	224(20)
14	419 (40)	401 (39)	432(19)	398(19)	447(10)	431(10)	256 (40)	254 (40)	281(21)	256(21)	259(20)	247(20)
18	454 (38)	432 (37)	483(19)	443(19)	486(10)	460(10)	286 (38)	282 (37)	281(21)	278(21)	302(20)	287(20)
22	482 (38)	455 (37)	513(18)	471(19)	519(10)	478(10)	300 (38)	291 (38)	309(21)	294(21)	291(20)	290(20)
26	501 (38)	461 (37)	548(19)	501(19)	522(10)	497(10)	305 (38)	293 (38)	307(21)	307(21)	325(20)	312(20)
30	525 (36)	494 (35)	578(19)	522(19)	540(10)	517(10)	312 (36)	303 (36)	307(21)	307(21)	323(20)	310(20)
35	558 (36)	504 (34)	Sacrificed after 30 weeks				311 (36)	301 (36)	319(21)	314(21)	325(20)	311(20)
52	651 (36)	584 (32)	.....	.....	.....	.....	340 (35)	324 (35)	Sacrificed after 35 weeks			
65	672 (31)	593 (27)	.....	.....	.....	.....	364 (32)	334 (65)	.....	.....	.....	.....
78	714 (25)	593 (21)	.....	.....	.....	.....	387 (32)	365 (25)	.....	.....	.....	.....
91	646 (14)	610 (9)	.....	.....	.....	.....	406 (24)	369 (15)	.....	.....	.....	.....
104	626 (5)	597 (7)	.....	.....	.....	.....	447 (17)	384 (9)	.....	.....	.....	.....
Standard errors: Week:												
14th	± 5.2	± 4.7	±11.9	±9.6	±11.6	±5.9	±4.5	±4.9	±5.5	±5.8	± 6.1	±3.4
30th	± 6.6	± 6.6	±19.2	±9.3	±24.3	±9.1	.....	.....	.....	.....	.....	.....
35th	.....	.....	.....	.....	.....	.....	±4.6	±4.9	±6.1	±6.7	±10.0	±5.9
52nd	±10.9	±12.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
78th	±15.6	±23.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
104th	±30.7	±34.9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

[1] Numbers in parentheses represent numbers of animals averaged at each point. Decreases represent mortality, sacrifices or animals not weighed for some reason, e.g., whelping.
[2] About ½ of each sex in each group was supplemented orally with tocopherol, beginning 11th week. See Table 3.
[3] All rats were supplemented orally with tocopherol beginning when about 18 days of age.
[4] One day short of 10 weeks.

11th experimental week (the reasons for giving this supplement will be discussed in detail later). Data in Table 3 show that the supplement did not affect significantly the weights of the males or females in either dietary group with the possible exception of the first generation control males. The unsupplemented subgroup of first generation control males did become significantly larger than the supplemented subgroup by 30 weeks. This growth difference possibly resulted from an uneven distribution of the animals, based on body weight, into subgroups. All animals saved for the second generation received the supplement beginning about 18 days of age; the weights of the experimental males and females did not differ significantly from the control animals.

TABLE 3

Adult weights of unsupplemented and dl alpha tocopherol supplemented subgroups of first generation rats fed diets containing raw or irradiated beef hamburger

End of Week	Males—Average weights in grams				Females—Average weights in grams			
	Control		Experimental		Control		Experimental	
	Unsupplemented	Supplemented	Unsupplemented	Supplemented	Unsupplemented	Supplemented	Unsupplemented	Supplemented
10	389	384	374	358	227	224	225	218
14	440	425	407	390	284	277	260	251
18	492	476	442	445	276	286	276	281
22	533[1]	498	572	471	306	312	293	295
26	566	531	507	495	308	306	306	309
30	596	562	528	516	305	309	310	303
35	.....	.....	.....	.....	317	322	312	316
Av. gain[2] and standard error	207±18.5	178±14.8	154±10.0	158±13.7	90±8.3	98±5.8	87±5.1	98±8.4
No. animals in each subgroup	9	10	9	10	10	11	11	10

[1] Average represents 8 animals; weighing of one animal was omitted inadvertently.
[2] For period beginning with 11th week, when divided into subgroups for supplementation, and extending to 30th or 35th week when discarded.

Food Utilization

The diets were readily accepted by both experimental and control rats, and, for the most part, the amounts consumed were similar as is shown in Table 4. The similarity continued through at least the 43rd week of the experiment. However, for the 57th to 60th weeks period, the food consumption of the experimental males had become significantly less than that of the controls. The decreased food consumption by the experimental males at this point is correlated perhaps with their significantly smaller size at this age (Table 2). The slightly smaller food consumption of the experimental females was not significant.

The efficiency of food utilization for both control and experimental animals also was excellent in all cases. However, in several instances the experimental animals did not utilize the food consumed quite as efficiently as the control animals. The differences (Table 4) were quite small, but they were highly significant for the parent generation males and females and were significant for the first generation males. The second generation males and first generation females showed no significant differences in efficiency of food utilization while second generation experimental females utilized food more efficiently than the control females, the difference being highly significant. In those instances where the food efficiency was less the males showed a different pattern from the females in that the food consumption was similar, but the experimental males gained a little less; for the females the gains were similar but the experimental females ate a little more food and utilized it less efficiently.

A trend toward increased efficiency of food utilization, usually rather pronounced, was observed for each succeeding generation within each dietary group and sex. If again the assumption is made that a direct comparison of one generation with the

TABLE 4

Food solids consumed and efficiency of food utilization[1]

	First 9 weeks		40-43 weeks	57-60 weeks
	Average solids eaten	Food/gain and standard error	Average solids eaten and standard error	Average solids eaten and standard error
	grams		*grams*	*grams*
Males				
Control (P)	831(40)	2.68 ± 0.02	351 ± 5.7(36)	360 ± 8.8(32)
Exptl (P)	831(39)	2.78 ± 0.02	347 ± 6.4(33)	325[2] ± 13.4(28)
Control (1)	801(19)	2.55 ± 0.03	Rats sacrificed	.....
Exptl (1)	796(19)	2.67 ± 0.04	Rats sacrificed	.....
Control (2)	800(10)	2.48 ± 0.04	Rats sacrificed	.....
Exptl (2)	791(7)	2.43 ± 0.05	Rats sacrificed	.....
Females				
Control (P)	599(40)	3.65 ± 0.03	243 ± 4.6(36)	242 ± 6.5(32)
Exptl (P)	614(40)	3.81 ± 0.03	241 ± 4.5(36)	236 ± 6.4(32)
Control (1)	573(21)	3.48 ± 0.04	Rats sacrificed	.....
Exptl (1)	580(21)	3.53 ± 0.07	Rats sacrificed	.....
Control (2)	583(20)	3.43 ± 0.05	Rats sacrificed	.....
Exptl (2)	546(20)	3.24 ± 0.04	Rats sacrificed	.....

[1] Numbers in parentheses refer to numbers of animals; letters in parentheses refer to generation —(P) = parent, (1) = first, (2) = second generation.
[2] Excluding one animal which ate only 50 g. of food solids.

succeeding one is valid, then the increased efficiency of food utilization would be highly significant in every comparison within dietary groups and sexes except those made between (a) the control males of the first and second generations, and (b) the control females of the first and second generations. The increases in these instances would not be significant, although approaching significance for the males ($P < 0.13$).

These and previous comparisons between generations have been made to emphasize the trend toward better rather than poorer growth and food utilization with each succeeding generation.

Such comparisons demonstrate the overall nutritional adequacy of the diets as well as the absence of a cumulative trend toward poorer performance which might have resulted from cumulative effects of unwholesome substance(s), if present.

Reproduction

The females of each group of the parent generation were mated with males receiving the same diet, at the beginning of the 11th week. One-fourth of the females of each dietary group of the parent generation was mated with males receiving the same diet at the beginning of the 11th week; another fourth was mated two weeks later, etc., until all females had been mated. Each female was caged with a male for one week. At the end of the week a different male was provided. A third male was used for a third week. The females were then isolated for 2 weeks. If pregnancy did not become evident, the cycle was then repeated with additional males. Gravid females were transferred to 41.9 × 25.4 × 17.8 cm. fine mesh cages which were supplied with tissue paper for nesting and examined daily for birth of litters or resorptions. The number of pups counted when the litter was first found was recorded as *pups born*.

Parent generation. The fertility of both control and experimental animals of the parent generation was good (Table 5). The same numbers of first litters were produced. In the second litters there may have been an indication that the fertility of the experimental rats was slightly less than that of the controls. A slightly higher percentage of the experimental females were either difficult breeders or sterile (5.4% for the control compared with 11.4% for the experimental females).

TABLE 5
Summary of reproduction

		Parent generation		First generation				Second generation		Summary
		None supplemented		Unsupplemented		Supplemented		All supplemented		(All generations)
		First litters	Second litters	First litters	Second litters	First litters	Second litters	First litters	Second litters	
Fertility										
Males[1] siring one or more litters	Control	35/40		8/9		7/10		10/10		30/69 = 87%
	Exptl	30/39		4/9		6/10		10/10		50/68 = 74%
Females whelping litters	Control	38/39	35/37	10/10	10/10	11/11	11/11	19/20	17/18	151 litters/80 females
	Exptl	38/39	31/35	8/10	5/8	10/11	9/10	20/20	19/20	140 litters/80 females
Av. days mated before conception occurred[2]	Control	8.8	8.4	4.4	13.8	5.8	7.8	13.8	8.4	Av. 9.2 days (151 pregnancies)
	Exptl	9.8(37)	9.1(30)	15.8	10.6	16.7	12.3	13.3	14.1	Av. 11.7 days (138 pregnancies)
Pup Mortality										
Pups born[3] per litter	Control	10.0	7.9	9.5	9.7	8.5	11.8	10.0	9.9	1404 pups/150 litters av. 9.4
	Exptl	8.3	8.6	7.3	4.8	7.3	9.0	7.2	8.3	1121 pups/139 litters av. 8.1
Per cent found alive	Control	89.5	88.0	88.4	99.0	81.5	96.4	92.1	96.8	1287/1404 = 92%
	Exptl	87.0	93.1	98.3	62.5	94.5	100.0	78.4	89.2	997/1121 = 89%
Per cent of those found alive dying by 9th day	Control	29.9	17.0	28.4	4.1	31.9	9.8	20.6	32.0	323/1404 = 23%
	Exptl	27.8	13.7	20.7	33.3	20.5	7.4	48.6	29.8	276/1121 = 25%
Per cent pups discarded[4]	Control	1.3	2.2	0	7.2	0	4.5	2.6	3.2	38/1404 = 2.7%
	Exptl	0.3	2.3	0	0	1.4	2.5	1.4	1.2	12/1121 = 1.1%
Per cent survival[5] (21 days)	Control	58.2	69.6	60.0	94.4	59.6	85.0	71.4	59.7	917/1366 = 67%
	Exptl	57.4	77.3	77.6	29.2	73.6	92.4	28.9	58.2	694/1109 = 63%
Weanling mortality (21st-36th day)	Control	.....	0	0	0	0	0	0	0	0
	Exptl	.....	37	3	3	0	0	0	0	43[6]
Weaning Data										
No. litters weaned	Control	26/38	24/35	8/10	10/10	7/11	10/11	16/19	11/17	112/151 = 74%
	Exptl	25/38	27/31	7/8	2/5	7/10	8/9	7/20	13/19	96/140 = 69%
Av. pups in litters weaned	Control	8.4	7.8	7.1	8.5	8.0	9.1	8.1	8.4	917 pups/112 litters av. 8.2
	Exptl	7.2	7.5	6.4	3.5	7.6	9.1	5.9	7.1	694 pups/96 litters av. 7.2
Av. male weaning wts. (21 days) gm[7]	Control	45.8(112)	50.6(92)	47.7(26)	44.5(43)	45.8(35)	42.5(44)	42.2(54)	46.8(53)	46.1 (459)
	Exptl	42.5(85)	43.8(100)	46.3(26)	57.0(3)	44.2(28)	44.6(32)	49.9(28)	49.7(54)	45.5 (356)
Av. female weaning wts. (21 days) gm[7]	Control	43.8(106)	47.8(96)	45.5(31)	43.2(42)	42.1(21)	40.2(47)	40.6(76)	45.3(39)	43.8 (458)
	Exptl	42.9(96)	42.3(102)	46.6(19)	57.0(4)	42.1(25)	44.5(41)	44.9(13)	48.2(38)	44.6 (338)

[1] The data indicate proved fertility. The rotational mating procedure used did not afford equal or adequate opportunity to all males to demonstrate fertility. Hence, failure to produce a litter does not necessarily indicate a lack of fertility.

[2] The number of conceptions used to calculate the averages is identical with the number of conceptions listed under "females whelping litters" except in the experimental group, parent generation, both first and second litters, where one female was left out for each because of unusually long periods before conception occurred (69 days and 65 days, respectively).

[3] Pups "born" refers to the number of pups counted upon initial discovery of litters (checked daily).

[4] Litters were reduced to 10 pups between the 4th and 6th day.

The first litters produced by both groups of parent generation animals were comparable. The only statistically significant difference observed was a smaller number of pups counted for females on the experimental diet. A rather high early mortality was observed in both the control and experimental litters, the cause of which is unknown.

In the second litters from parent generation animals fewer pups were born, but the early mortality declined. The per cent survival increased and was the highest for the experimental group.

The average weaning weights of all pups born to those parent generation females which weaned two[f] litters each were significantly higher for the control group than for the experimental group. The difference in weaning weights was small and not quite significant in the first litters; the difference in the second litters was larger and highly significant. Second litter weaning weights were larger than for first litters with the exception of the experimental female weanlings and the difference was significant.

The most obvious difference between the control and experimental pups from the parent generation appeared about the time of weaning, or shortly thereafter, when a considerable number of the second litter pups in the experimental group died. These deaths often occurred without observable symptoms and with little or no loss of body weight. In other animals, symptoms observed were marked edema of the face, ruffled hair coat, general incoordination, spastic hopping gait, and sometimes complete loss of movement with dragging of the hind quarters. Those pups most severely affected often became completely prostrated a short time before death. The most striking aspect was the marked suddenness of onset. Litters affected were usually of good weights and would appear perfectly healthy a few hours prior to the time when first symptoms and deaths were noted. In no case were these symptoms noted in the control group.

The above condition was entirely unexpected and most first litter pups were discarded at weaning (21 days) before it became evident. Two experimental first litter pups showed slight symptoms of a seemingly transient nature which were followed by apparently complete recovery. Sixteen pups of the second litters of the experimental parent generation were not kept beyond the 21st day. However, because of abnormalities in these pups, all the pups in subsequent litters were maintained for at least a week after weaning on their respective diets and then for another week on a stock diet before discarding.

Thirty-one of the 202 experimental pups (the first generation) were sacrificed for either histopathological or hematological examination shortly after weaning, and 2 litters totaling 16 pups were discarded when weaned on the 21st day. Some of these pups were in apparent good health and others were in a terminal condition. Forty-three pups died during the weaning period. Six died during the 18-21 day interval and 37 died within 10 days during the two week observation period after weaning. All deaths occurred in 14 of the 27 litters weaned. Pups in two other litters showed symptoms but did not die. Usually only a few pups in an affected litter would die and in no case did all die. It is possible that if the 31 pups sacrificed for histopathology and hematology and the 16 pups discarded at weaning had been given an opportunity to live for two additional weeks for observation, the total mortality of weanlings (21st to 36th day) might have been higher than the 37 deaths out of 202 pups weaned (or 18%) indicated in Table 5. The surviving animals discarded after the 36th day generally appeared normal in all respects.

The abnormality described above was strikingly similar to that first described by Evans and Burr *(6)* in the suckling young of female rats being maintained on a vitamin E low diet. Their observations have been confirmed repeatedly by others. The efficacy of synthetic DL alpha tocopherol in preventing the condition was demonstrated later *(1, 2, 8)* and has been confirmed in many laboratories. The probability that the second litter sucklings and weanlings were suffering from the characteristic muscular dystrophy syndrome (commonly referred to as nutritional muscular dystrophy) known to result from a marginal vitamin E intake was enhanced by the observation of a high degree of hemolysis of the red cells of the parent generation experimental animals by dialuric

[f] For convenience in statistical treatment only those rats were used which had produced two litters. The average weaning weights were similar to those in Table 5.

acid, using the technique reported by Rose and Gyorgy *(20)*. The control animals showed no appreciable hemolysis. Results of the dialuric acid hemolysis tests are reported in more detail under Hematology and Blood Analyses.

First generation. The above observations indicating a probable marginal vitamin E intake for the experimental animals led to modification of the procedure originally planned for the first generation animals in that the experimental and control animals were subdivided into unsupplemented and supplemented groups (one-half of each sex). Shortly after weaning, animals were selected from the second litters whelped by parent generation females. Where possible 2 males and 2 females were selected from each litter, one male and one female weanling going to each group. Thus the subgroups represent mostly a series of littermate pairs. Only healthy-appearing, representative pups were selected. Extremes in size were avoided. Supplementation was started just prior to mating at 14-15 weeks of age. The supplement consisted of 10 mg. synthetic DL alpha tocopherol dissolved in 0.1 ml. wheat germ oil administered orally to each animal about 8:00 A.M., Monday through Friday. Since the daily feeding usually was made about 3:00 P.M., possibility for the diet to destroy any of the supplemental DL alpha tocopherol by contact within the stomach or intestines was minimized.

The reproductive data for first generation animals tabulated in Table 5 indicate that a reduced degree of fertility probably existed in the unsupplemented experimental animals. There is also an indication that supplementation improved the fertility of the experimental animals, particularly during the period of second litter matings. The fertility of the control group remained high and unaffected by supplementation.

The survival to weaning of pups of the supplemented, experimental, first generation litters excelled that of the controls. Symptoms and mortality (three pups after weaning) were observed in 3 of the 8 first litters born to unsupplemented, experimental, first generation females.

The performance of the first generation in producing second litters was excellent for all animals except those of the unsupplemented experimental subgroup. Here, 3 females which weaned first litters failed to conceive a second time, 3 of 5 litters were lost, and only 7 of 24 pups born were weaned. All 7 pups became sick by the 23rd day, showing the characteristic symptoms previously described; 4 were sacrificed for histopathology and the remaining 3 died by the 26th day.

Second generation. The animals saved for the second generation were selected from the second litters whelped by supplemented first generation females of both dietary groups. Each second generation animal saved had been supplemented, starting about 18 days of age.

The reproductive success of the second generation (Table 5) indicates a continued high fertility for the control group and an equally high fertility for the experimental group. However, 13 out of 20 first litters born to the experimental group were lost prior to weaning age. The average number of pups born per litter was low. This poor performance did not occur in second litters. Second litters of control and experimental second generation females were comparable.

The results demonstrate the complete success of the supplement of DL alpha tocopherol in wheat germ oil in preventing the paralytic symptoms and sudden death observed in experimental weanling pups, thus affording direct evidence that the condition was nutritional muscular dystrophy.

Hematology and Blood Analyses

Routine hematological examinations (red cell count, white cell count, differential count and hemoglobin content) were conducted on 64 parent generation females (16 males and 16 females from each group) during the 11th experimental month. Fifty-six survivors of this sample were examined again during the 15th experimental month. Finally 39 survivors were examined after 20 months.

The blood picture did not present anything unusual for either dietary group. Such differences as did exist appeared incidental and small enough that statistical analysis was judged by the authors and statistician as unnecessary to establish a lack of any effect of irradiation of the meat component of the diet on blood morphology.

In addition to these planned hematological examinations, dialuric acid hemolysis

tests[a] were made where the vitamin E status of the animals was questioned. A total of 64 blood samples from 42 parent generation animals were subjected to this test from the 38th through the 55th week of experiment. All of the 31 samples from 20 control animals showed less than 7% hemolysis; 25 samples showed no hemolysis and the overall average hemolysis was 1%, thus showing no indication of deficiency. On the other hand, 32 of 33 samples from 22 experimental animals showed more than 81% hemolysis, averaging 91%, definitely indicating the probable existence of a tocopherol deficient state in these unsupplemented parent generation animals.

The test was applied also to 46 first generation animals (49 blood samples taken during the 20th-28th week on experiment). Twenty-four samples from 24 control animals showed no hemolysis, whether or not supplemented with DL alpha tocopherol in wheat germ oil. Likewise, 12 experimental animals receiving the supplement showed no hemolysis (12 blood samples) indicating that the supplementation corrects the deficiency. Thirteen samples from 10 unsupplemented experimental animals showed more than 67% hemolysis, averaging 93%.

When the test was applied during the 27th through the 33rd week on experiment to the second generation animals, all of which had been supplemented beginning about 18 days of age, single samples from 12 control and 14 experimental animals showed little or no hemolysis, thus again indicating the effectiveness of the supplementation in correcting the deficient state otherwise existing. The control bloods showed less than 7% hemolysis, averaging 0.8%; the experimental samples less than 15%, averaging 1%.

Mortality and Life Span

Data in Table 6 show that the survival of the parent generation animals was good for both the control and experimental dietary groups throughout the first year. Most of the mortality occurred during the last 6 months of the 2-year period. Approximately equal numbers of male animals survived the 2-year period in each group (5/30[b] controls and 7/30 experimentals). Greater numbers of female animals survived than males, and substantially more control females (17/30) than experimental females (9/30). The average life span was very good for both groups, although significantly shorter for both sexes of the experimental group.

First and second generation animals were sacrificed for gross pathology when reproduction was completed (after 30 weeks for males and 35 weeks for females). No first generation control animals died. Four experimental animals in the first generation died during the first week, possibly of vitamin E deficiency. The 4 dead were replaced with 4 additional weanlings from the same group, after which there was no further mortality.

In the second generation two control females died, in the 25th and 29th weeks respectively.

In the parent generation those animals which were observed to be in a "terminal condition," i.e., almost certain to die soon, were sacrificed, in many instances for reasons explained later. Although it was realized that the life span of animals so sacrificed may have been shortened artificially thereby, these animals were included with those found dead in the mortality data in Table 6.

Neoplasms

As expected in long term experiments, a few animals showed "enlargements" which might have been neoplasms or tumors, cysts, abscesses, etc. Table 7 shows that the neoplasms (confirmed by gross and/or histopathology) were distributed approxi-

---

[a] This test, described by Rose and Gygory *(20)*, correlates the degree of *in vitro* hemolysis by dialuric acid with the tocopherol status of the rat, deficient animals showing a high degree of hemolysis by dialuric acid. The authors are indebted to Dr. Catherine S. Rose for a personal communication detailing the technique and for providing the first sample of dialuric acid used in our tests.

[b] Ten of the original 40 animals started were not included, inasmuch as these animals were sacrificed routinely for histopathology and therefore did not have a chance to survive the entire two-year period.

TABLE 6
Summary of Mortality and Sacrifice

	Parent generation				First generation				Second generation			
	Males		Females		Males		Females		Males		Females	
	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl
No. of rats started	40	40	40	40	19	22	21	22	10	10	20	20
Cumulative mortality:[1]												
(A) end of 30 weeks	0	1	0	0	0	3	0	1	0	0	2	0
(B) end of 52 weeks	0	4	1	1	Sacrificed after 30 to 35 weeks							
(C) end of 78 weeks	8	11	1	8	....	....	....	....	....	....	....	....
(D) end of expt—104 weeks	25	23	13	21	....	....	....	....	....	....	....	....
Sacrificed for histopathology:												
(A) during expt	10	10	10	10	0	0	0	0	0	0	0	0
(B) end of expt	5	7	11	9	0	0	1	0	0	0	1	3
Sacrificed for gross pathology only at end of expt	0	0	6	0	19	19	20	21	10	10	17	17
Average days survival[2] (on expt) and standard error	614 ± 18.8	581 ± 24.9	685 ± 14.7	612 ± 21.8	....	....	....	....	....	....	....	....

[1] Includes those animals sacrificed in a terminal condition to obtain tissues for histopathology; does not include animals sacrificed routinely during and at end of experiment for histopathology.

[2] Exludes animals sacrificed routinely during experiment for histopathology, but includes those sacrificed in a terminal condition. Also excludes one animal in the experimental male group which died early (19 days), and another in the experimental female group which was killed accidentally (511 days). Potential life span was limited experimentally to 728 days. Life span of experimental animals was significantly shorter for both sexes ($P<0.05$).

mately equally between the control and experimental animals. The pathologist listed 6 animals with 6 malignant neoplasms and 9 animals with 12 benign neoplasms in the control group. In the experimental group there were 4 animals with 4 malignant neoplasms (one of which was questionable), 9 animals with 10 benign neoplasms (two of which were questionable), and one animal whose neoplasm could not be classified histologically because of accidental loss of the section. Most of the neoplasms occurred in 141 animals of the parent generation after 300 days on the experiment. The similar incidence and miscellaneous pattern in location and type point toward "spontaneous" origin completely unrelated to irradiation of the meat ingredient of the diet.

Special attention was given throughout the experiment to searching for possible neoplasms in both living and dead animals in order to minimize the possibility of overlooking any which occurred.

Gross and Histopathology

Equal numbers of males and females from each dietary group of the parent generation were selected by drawing numbers for gross and histopathological examination after 3 and 6 months on experiment (8 animals each time) and after 12 and 18 months (12 animals each time). On termination of the experiment, after 24 experimental months, all surviving animals in the experimental group (7 males, 9 females) and a comparable number of control animals were taken for histopathological examination. The remaining survivors (6 control females) were sacrificed and examined grossly.

In addition to planned sacrifices for histopathology, any animals found in a "terminal condition," i.e., almost certain to die soon, were, in many instances, sacrificed in order to obtain fresh tissue samples. The only exception regularly made was the exclusion of animals whose terminal condition appeared to be due obviously to severe chronic respiratory disease. In some instances, tissues appearing to be abnormal grossly were saved from animals found dead, and an attempt was made to obtain the best histological preparation possible from such material; particular attention in this regard was given to tissues which appeared possibly neoplastic.

When the unexpected symptoms and mortality were observed in the second litter offspring of the parent generation of experimental animals, special arrangements were made for the histopathological examination of 6 control and 18 experimental weanlings. Most of the animals examined were sacrificed, although some had died just before examination. In addition, a histopathological examination was made of a sample more uniform in number and distribution and representing the second litters of the first and second generations. Six supplemented and 6 unsupplemented weanlings in each dietary group of the first generation and 14 control and 11 experimental weanlings of the second generation (all supplemented) were examined.

After the conclusion of the reproductive phase (35 experimental weeks for the females and 30 for the males) the first and second generation adults were sacrificed and examined grossly. In addition the liver, spleen, kidneys, and testes of most animals were weighed.

The following tissues were saved routinely from most animals selected randomly for histopathological examination: reproductive organs, kidneys, adrenals, spleen, pancreas, stomach, small intestine (duodenum, ileum and/or jejunum), colon, liver, lungs, mediastinal structures, lymph nodes (usually mesenteric and/or cervical), thymus, and bone marrow. Skeletal muscle was usually included subsequent to the observation of paralytic symptoms in weanlings. Frequently but less regularly examined were the cecum, urinary bladder, salivary glands and central nervous system. Occasionally other tissues were sampled, e.g., all neoplasms were included, as well as still other apparent gross abnormalities at the discretion of the pathologist conducting the autopsy. In animals found dead histopathology, if done, was limited usually to those tissues appearing to be abnormal grossly. Differential marrow smear counts were made on a substantial number of animals.

Nearly all histopathological and most of the gross examinations were made by Dr.

TABLE 7
Summary of neoplasms

Group	Histological classification and description		Location	Days on experiment	
				First noted[1]	Autopsied
Parent generation					
Control males	Malignant	Pharyngeal carcinosarcoma	Pharynx	342	368
	Malignant	Small mixed tumor (carcinomatous)	Parotid	441	476
	Benign	Large cortical adenoma	Adrenal	—	554
	Malignant	Mediastinal lymphosarcoma (4 g.)	Anterior mediastinum	—	634
Control females	Malignant	Mixed tumor in orbits, bilateral, infiltrating brain	Orbital	279	348
	Malignant	Large retroperitoneal fibrosarcoma	Peritoneal cavity	—	592
	Benign	Two fibro-adenomas (33 & 115 g.)	Mammary (two)	524	616
	Benign[6]	Small dermoid cyst	Thorax		
	Malignant	Fibrosarcoma	Peritoneal cavity	679	711
	Benign	Fibro-adenoma (6 g.)	Right axilla	707	729[2]
	Benign	Fibro-adenoma (125 g.)	Mammary	581	729[2]
	Benign	Fibro-adenoma (12 g.)	Mammary	686	733[2]
	Benign	Adenoma (17 g.)	Mammary	672	734[2]
	Benign	Two adenomas (5 & 6 g.)	Mammary (two)	469	735[2]
	Benign	Fibro-adenoma (11 g.)	Mammary	672	735[2]
Experimental males	Malignant	Small neurofibrosarcoma	Right face	336	449
	Benign†	Fibroma (possibly fibrosarcoma) ((11 g.)	Thorax	—	634
	Benign	Fibroma (medium size)	Side of head	236	707
Experimental females	Benign	Fibro-adenoma (112 g.)	Mammary	315	456
	Benign	Fibro-adenoma (166 g.)	Mammary	315	456
	Benign†[4]	Small cellular fibroma	†[3]		
	Benign	Fibro-adenoma (294 g.)	Mammary	399	546
	Benign	Adenoma (95 g.)	Mammary	497	562
	Benign	Fibro-adenoma (2 g.)	Ovary[3]	431	575
	Malignant	Large carcinoma, undifferentiated	Peritoneal cavity	—	594
	Malignant	Fibrosarcoma (175 g.)	Perineal region	644	705
	Benign	Fibro-adenoma (18 g.)	Mammary	693	734
First generation		No neoplasms noted in any groups			
Second generation					
Control females	Benign	Fibro-adenoma (40 g.)	Mammary	188	252
Experimental females	Benign	Small fibro-adenoma	Mammary	—	245
	Malignant†	Lympho-epithelionic tumor (8 g.)	Anterior neck region	140	245
	†[5]	Small cystic tumor	Left masseter muscle	—	245

[1] Dash indicates neoplasm was not noted prior to autopsy.
[2] Although experiment was "terminated" at 728 days, some animals were continued on test for a short time until it was possible to sacrifice them.
[3] No autopsy by pathologist; location was not recorded.
[4] Classification questionable without knowledge of location.
[5] [illegible] histopathological examination in permit classification.

John B. Fuller.[i] He usually sacrificed the animals (taken to his laboratory for this purpose), and reported his observations under autopsy code numbers which had been assigned to prevent any knowledge on his part of the identity and treatment of each specific animal examined; in addition, he had only a very general knowledge of the nature of the experiment prior to completing his observations.

The examination of hemotoxylin and eosin preparations of central nervous system tissues by Dr. Fuller was supplemented by further examination by Dr. Arthur Arnold,[j] using techniques specially applicable to such tissues. This was done as an exploration in recognition of the fact that the usual hemotoxylin and eosin tissue preparations may not reveal all pathology in such tissues. A small cross-section of 20 animals covering most groups was so examined with negative findings.

A total of 432 animals were autopsied during the course of the experiment. A gross examination only, including weights of principal organs in many instances, was made on 249 of the 432 animals. Such examinations were limited mostly to weanlings and young adults and were negative in that they revealed no unusual gross lesions which might have been evidence of harm to the animal resulting from the consumption of irradiated meat. For the sake of brevity these negative data have not been included in this publication.

A total of 2571 tissues were examined histologically from the remaining 183 animals brought to autopsy. This number includes those which were selected randomly for such examinations, and other animals in which a gross examination had revealed unusual lesions requiring histopathological characterization.

As shown in Table 8, most of the tissues examined were normal (2037/2571 total; 970/1224 control and 1067/1347 experimental). It so happened that the percentage of normal tissues was the same (79.2%) for both the control and experimental groups.

The 534 tissues which were not normal showed a total of 632 histological deviations.[k] Although it is not practical to tabulate here all of the deviations observed, Table 8 does show those which occurred three or more times in any one or more of the groups and subgroups listed across the top of the table. Thus 412 deviations are classified out of a total of 632 which were observed in the 2571 tissues examined from 183 animals. The degrees of severity for the deviations varied from slight to quite severe and are not shown.

The 412 deviations tabulated as occurring most frequently are classified into 18 types according to the nature and location of the deviation. On a similar basis, the 220 deviations lumped into the category *other miscellaneous* represent an additional 107 types.

The deviation occurring most frequently was hemosiderosis of the spleen; it was found in nearly all adult animals, both control and experimental; its significance is obscure.[l] Testicular atrophy, decreased spermatogenesis, extramedullary hematopoiesis in the spleen, and fatty livers were the deviations next most frequent in occurrence; again the distribution between the control and experimental groups was nearly the same. These 4 deviations alone account for 230 of the 632 deviations observed (36.4%). Other deviations occurring in adult animals were spontaneous, heterogeneous changes

---

[i] Dr. Fuller, Associate Professor of Pathology and Assistant Director of the Hospital Laboratory, Research & Educational Hospital, College of Medicine, University of Illinois, 808 Wood Street, Chicago, Illinois, conducted and reported the pathological examinations of the animals and tissues, including differential marrow smear counts on some animals.

[j] Dr. Arthur Arnold, Assistant Professor of Neurology and Neurosurgery, Department of Neurology and Neurological Surgery, Neuropsychiatric Institute, College of Medicine, University of Illinois, 912 Wood Street, Chicago, Illinois, conducted and reported special histopathological examinations of central nervous system tissues.

[k] Deviation as used here does not necessarily imply pathological significance, but represents any condition which the pathologist saw fit to describe rather than calling it "normal." A single tissue may show more than one deviation in some instances.

[l] Moderate to severe hemosiderosis of the spleen was found in 4 rats which had been maintained on a stock diet for 35-40 weeks. The animals were obtained from the same source nearly two years later and raised in the same animal room. The implication is that hemosiderosis of the spleen of adult rats may be characteristic of this strain and/or this environment.

[illegible] Dash indicates neoplasm was not noted prior to autopsy.
[illegible] Although experiment was "terminated" at 728 days, some animals were continued on test for a short time until it was possible to sacrifice them.
[illegible] No autopsy by pathologist; without knowledge of location.
[illegible] Classification of tissues without knowledge of location.

TABLE 8
Summary of histopathological observations[1]

	Parent generation												First Generation		Second generation						Third Generation		Totals		
	3 months		6 months		12 months		18 months		24 months		Terminal or died[2]				Weanlings				Adults[3]						
															Unsupplemented		Supplemented		Supplemented						
	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl	All Groups
Number animals examined	4	4	4	4	6	6	6	6	17	16	16	17	6	18	6	6	6	6	1	3	14	11	86	97	183
Number tissues examined	65	62	69	63	98	98	106	83	238	222	99	113	120	329	97	80	106	89	18	47	208	161	1224	1347	2571
Number tissues normal	60	57	62	52	83	79	73	59	152	137	24	54	119	300	93	56	101	82	10	40	193	151	970	1067	2037
Number deviations observed	5	5	7	12	16	22	43	30	113	102	90	72	1	28	4	25	5	7	9	10	16	10	309	323	632
Hemosiderosis—spleen	4	4	4	4	6	6	6	6	15	16	6	6	0	2	0	0	0	0	1	3	1	0	43	47	90
Hemosiderosis—lymph nodes—various sites	0	0	0	3	1	2	1	2	2	4	0	1	0	0	0	0	0	0	0	0	0	0	4	12	16
Testicular atrophy and decreased spermatogenesis	0	0	0	0	1	3	6	4	9	12	9	5	0	3	0	0	0	0	0	0	0	0	25	27	52
Extramedullary hematopoiesis—spleen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	6	5	5	1	3	13	10	23	24	47
Fatty change—liver	1	1	0	0	0	0	3	1	12	8	4	5	1	2	0	1	0	2	0	0	0	0	21	20	41
Bronchitis, pneumonitis or pneumonia	0	0	0	0	0	0	4	3	9	12	5	3	0	1	0	0	0	0	1	1	0	0	19	20	39
Degenerative changes—skeletal muscle	....	....	....	0	0	0	1	2	1	4	0	0	0	12	0	6	0	0	0	0	0	0	2	24	26
Neoplasms—benign	0	0	0	0	0	0	0	0	7	1	4	8[5]	0	0	0	0	0	0	1	1[4]	0	0	12	10	22
Neoplasms—malignant	0	0	0	0	0	0	0	0	1	0	5	3	0	0	0	0	0	0	0	1[6]	0	0	6	4	10
Atrophy—spleen	0	0	0	0	0	0	0	0	7	5	1	0	0	0	0	0	0	0	0	0	0	0	8	5	13
Atrophy—liver	0	0	0	0	0	0	0	0	2	1	4	3	0	0	0	2	0	0	0	0	0	0	6	6	12
Atrophy—skeletal muscle	....	....	....	0	0	0	0	0	2	2	3	1	0	0	0	0	0	0	0	0	0	0	5	3	8
Atrophy—ovary	0	0	0	0	0	0	0	0	5	2	1	0	0	0	0	0	0	0	0	0	0	0	6	2	8
Pyelonephritis	0	0	0	0	0	0	2	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	6	0	6
Ovarian cysts	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	1	0	0	0	5	1	6
Reticular hyperplasia—spleen	0	0	0	0	0	0	0	1	1	4	0	0	0	0	0	0	0	0	0	0	0	0	1	5	6
Enlarged spleen	0	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	3	2	5
Thickening of the media of central arteries of spleen	0	0	0	0	0	0	3	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	5	0	5
Other miscellaneous deviations	0	0	3	5	8	11	17	10	35	31	40	35	0	8	0	10	0	0	4	1	2	0	109	111	220

[1] A "zero" signifies tissues were examined but deviation was not found. Dashes indicate that the tissues were not examined.
[2] Histopathological examination of tissues of animals found dead, when done, was ordinarily limited to those tissues appearing abnormal grossly.
[3] These animals were examined histologically only because neoplasms were observed grossly.

having no pattern or trends in either the control or experimental dietary groups. The number and variety of such changes increased markedly with advancing age.

There were few unexplained abnormalities in weanling animals, and again an absence of any pattern or trends with one outstanding exception. The first generation experimental weanlings, in which a high incidence of muscular weakness and incoordination with sudden death had been observed grossly, showed a correspondingly high incidence of degenerative changes histologically in the skeletal muscles (12 out of 18 animals examined). Unsupplemented second generation experimental weanlings likewise showed mortality and gross muscular weakness as well as histological degenerative changes in the skeletal muscle; these abnormalities were prevented in the subgroup of second generation experimental weanlings receiving the supplement of DL alpha tocopherol in wheat germ oil. Likewise, these abnormalities were not observed in any of the third generation experimental weanlings, all of which received the supplement.

There were no real differences in organ weights between the control and experimental groups except for testes weights of the first generation experimental adults without supplementation. Supplementation increased the testes weights of the first generation experimental animals substantially, although they were still somewhat smaller than those of the controls. The testes weights of the second generation experimental animals, all of which received the supplement, were equal to the testes weights of the corresponding control animals.

TABLE 9

Testes weights at 35 weeks on test

	Number of animals		Average body weight		Average testes weight		Average % of body weight	
	Control	Exptl	Control	Exptl	Control	Exptl	Control	Exptl
			grams		*grams*			
First generation								
Unsupplemented	7	7	629	544	3.27	1.52	0.53	0.28
Supplemented	6	7	597	516	3.25	2.12	0.55	0.41
Second generation[1]	7	10	539	526	3.41	3.44	0.64	0.66

[1] All second generation animals were supplemented with DL alpha tocopherol.

Differential marrow smear counts were completed on 72 animals, 34 control and 38 experimental. The distribution by age and group in the parent generation was as follows: 6 months—control 4, experimental 4; 12 months—6, 6; 18 months—6, 5; 24 months—14, 14. Likewise, the distribution in the first generation was: weanlings—4, 9. The only consistent patterns noted in the differential marrow smear counts were (a) a progressive increase in myeloid/erythroid ratios owing to a progressive decrease in the proportion of red cell precursors associated with aging of the rats, and (b) a marked increase in the proportion of polymorphonuclear leukocytes, metamyelocytes and myelocytes in all rats with acute and subacute infections, such as pneumonitis, peritonitis associated with abdominal or pelvic tumors, etc. There were no indications that the deviations observed were related to the irradiation of the meat ingredient of the experimental diet. Tabulation of these negative data has been omitted for brevity.

DISCUSSION

It is clearly evident that both the control and experimental diets fed in this experiment supported an unusual rate of growth, leading also to an unusually large adult size (marked obesity) of the control males, particularly later in the life span. The females did not tend toward obesity as early as the males, usually becoming obese during the second year. It is believed that the tendency toward obeseness was a result of the highly

palatable, high meat, high fat diet fed *ad libitum* in conjunction with the limitation of activity associated with confinement in a cage.

The slightly smaller adult size of the experimental animals, males in particular, is probably correlated with the slightly poorer utilization of food observed for the experimental animals. The reason for the poorer utilization of food by the experimental animals is not determinable from the data. Although the irradiated meat was the only significant source of protein in the experimental diet, it is believed that a diminished nutritional quality of the meat protein by irradiation is not a probable explanation, since a preliminary experiment with beef hamburger irradiated with 5 million rep showed only a slight, probably insignificant, effect on protein quality evaluated under the stress conditions of a 5% protein level (based on diet solids). The irradiation process may have slightly lowered the overall nutritive value of the beef hamburger including caloric utilization. Since the hamburger is a major ingredient in the diet, any general effect on nutritive value would be reflected in a slightly lowered efficiency of utilization of the diet; conventional heat sterilization of the beef hamburger instead of irradiation might have produced a similar, perhaps larger, effect. The unusual rate of growth of the experimental animals, as well as the trend toward better growth and food utilization in subsequent generations rather than a cumulative decline, would seem to remove any real question regarding the wholesomeness of the irradiated beef.

The comparison of the reproductive performance of the experimental animals with that of the control is complicated to some degree by the demonstration that the tocopherol content of the experimental diet was reduced to a submarginal level by the irradiated meat component. However, the muscular dystrophy syndrome of the experimental sucklings and weanlings, which was the outstanding difference in reproductive performances, was shown clearly to be a result of the submarginal DL alpha tocopherol intake. The complete prevention of the condition by an oral supplement of DL alpha tocopherol shows that it probably was caused by a deficiency and not by a toxic substance.

The tendency toward declining fertility of the experimental group in the first generation was, as might be expected, reversed to a considerable extent in regard to litters born by supplementation with DL alpha tocopherol. The number of pups born per litter, another criterion of fertility, was improved also by the supplementation. The success in weaning pups was better. While the data demonstrate the role of DL alpha tocopherol as regards these criteria, there is also the possibility that other factors such as a slight decrease in general nutritional availability or some other effect of irradiation of the meat might have been involved also. In this connection, the overall experience of reproductive success for the control and experimental groups has been compared by groups in the last column of Table 5 without regard to generation, litter, or supplementation. Such a comparison for the considerable numbers of animals involved leaves little doubt of a substantially better reproductive performance of the control group in production of weanlings. However, the overall reproductive success of the experimental group is reasonably good in spite of the demonstrated effects of DL alpha tocopherol deficiency. The failure to equal

completely the control group in reproductive success may be due to the same factor(s) responsible for the slightly decreased efficiency of food utilization and smaller size of the experimental groups, thought to be, as previously discussed, possibly due to a slightly lower nutritional value. Retorting the meat instead of irradiating it might have caused a similar effect.

The survival of both control and experimental animals was very good, although the average life span of the experimental group was 5 to 7% shorter than the life span of the control for both sexes in the parent generation. No explanation is suggested by the results to account for this difference; it is not known whether the lower tocopherol content of the experimental diet could have caused a shortening of the life span. In this connection it should be emphasized that none of the parent generation animals were supplemented with DL alpha tocopherol at any time.

Nearly all of the histological abnormalities observed in both groups were those heterogeneous, spontaneous changes which would be expected in any aging group of rats. The only specific histological differences showing up in the experimental group when compared with the control were those of the condition which Mason *(15)* describes as early or explosive type of nutritional muscular dystrophy. This condition is known to result from a partial deficiency of DL alpha tocopherol and this, rather than the irradiated meat *per se,* was demonstrated to be the cause of the nutritional muscular dystrophy observed in this experiment. The incidence of benign and malignant tumors was quite similar for both groups, thus indicating that irradiation of the meat did not produce carcinogens demonstrable under the conditions of this experiment.

The most logical cause for the partial DL alpha tocopherol deficiency induced by the diet containing irradiated beef is destruction by oxidation of part of the tocopherol included in the diet. The existence of oxidizing conditions under the influence of irradiation has been demonstrated repeatedly and, more specifically, increased peroxide values of fats or fatty components of foods and linoleic acid autoxidation with increased peroxide formation have been reported several times *(3, 4, 9, 16, 17, 19).* Exploratory peroxide analyses of samples of irradiated meat used in this experiment, as well as other samples of irradiated meat not used in this experiment, have indicated slight but definite elevations of the peroxide values. Exploratory ultra-violet spectra of the fat rendered from irradiated meat have indicated shifts in the spectra toward increased general absorption characteristic of oxidized fats. It is probable that further increases in peroxide value may have occurred during the prolonged storage periods (as long as 6 months at −18°) necessary to insure the continuity of supply for the experiment. The mixing procedure wherein the diets were mixed and stored for periods up to 12 days provided ample opportunity for destruction of the added tocopherol by contact with the irradiated meat component. It was also found that a substantial loss of tocopherol occurred during the mixing into the diet premix of the wheat germ oil used as the source of tocopherol. The approximate extent of the destruction was indicated by analyses of the wheat germ oil and the finished diets for total tocopherol content by the method of Emmerie and Engel *(5).* The total tocopherol content of

the wheat germ oil was found to be 2.5 mg. per g.; thus the tocopherol added to each 100 g. of diet solids was about 2.6 mg. The total tocopherol contents for the control and experimental diets 3 days after preparation were found to be approximately 1.2 mg. and 0.3 mg. respectively per 100 g. of diet solids representing retentions of approximately 46% and 12% respectively, of the amount added initially. About 21% of the tocopherol added disappeared during preparation of the premix. During mixing the premix with raw beef hamburger to prepare the control diet an additional 33% of the tocopherol disappeared, compared with an additional 67% disappearing during mixing of the premix with the irradiated beef hamburger to prepare the experimental diet. Destruction of the tocopherol by the irradiated meat component of the experimental diet was just sufficient, apparently, to make the total DL alpha tocopherol content of the experimental diet submarginal for rats. The complete prevention of the nutritional muscular dystrophy and improvement of fertility of the experimental group following oral supplementation with DL alpha tocopherol demonstrate that irradiation was involved indirectly and only to the extent of producing conditions which enhanced tocopherol losses in the diet use.

SUMMARY AND CONCLUSIONS

Raw ground beef has been irradiated with two million rep of electrons (cathode rays or beta rays) and compared with similar raw ground beef not irradiated by feeding to albino rats through three generations (a total of 2685 animals). About two-thirds of the diet as fed was composed of meat, equivalent to about 45% of the diet solids or 60% of the calories. Results regarding growth, adult size, efficiency of food utilization, reproduction, hematology, survival, pathology, and neoplasms have been described.

The animals fed the irradiated beef over a life span (two years) and through successive generations performed very well. Once initial marginal deficiencies of vitamin E (due to destruction during mixing and storage of the diet) were corrected, no major differences existed between the control and experimental groups. No gross or histopathological lesions attributable to irradiation of the beef were observed. The small and occasionally statistically significant decreases in growth, food efficiency, reproduction, adult body size and survival were considered to be due to slightly decreased nutritional quality, similar to that which occurs during heat sterilization, and not an indication of toxic effects.

It is concluded that the data presented herein provide substantial evidence that treatment of beef muscle with a sterilizing dose (two million rep) of radiation of high velocity electrons does not significantly impair nutritional value or wholesomeness.

Acknowledgments

The authors wish to express their thanks to the following persons for their assistance with certain parts of the experimental work reported: C. M. Zoubek, T. R. Simonson and H. J. Czarnecki for preparation, irradiation, shipment and storage of the considerable quantities of control and irradiated meat required; Dr. H. P. Andrews for the statistical analyses; J. F. Beuk, Dr. John Hogan and Dr. F. W. Chornock for carrying

out the dialuric acid hemolysis tests and tocopherol analyses; M. G. Anderson, G. A. Werner and Jacquelin Lambert for hematology; B. N. Rockwood for proximate analyses of diets and ingredients; K. H. Spitzmueller for preparation of some of the dialuric acid used for hemolysis tests; Dr. A. L. Lingard for ultra violet spectral analyses of fats from irradiated meat.

LITERATURE CITED

1. BARRIE, M. M. O. Vitamin E deficiency in the suckling rat. *Nature*, 142, 799 (1938).
2. DEMOLE, V., AND PFATZ, H. Vitamin E deficiency and neuromuscular impairment in rats, and treatment with synthetic vitamin E. *Schweiz. Med. Woch.*, 69, 123-125 (1939).
3. DUBOULOZ, P., DUMAS, J., AND VIGNE, J. Presence of lipide peroxides in the skin after action of various physical agents. *Compt. rend. soc. biol.*, 144, 1080-1081 (1950).
4. DUNN, C. G., CAMPBELL, W. L., FRAM, HARVEY, AND HUTCHINS, ARDELIA. Biological and photo-chemical effects of high energy, electrostatically produced roentgen rays and cathode rays. *J. Applied Phys.*, 19, 605-616 (1948).
5. EMMERIE, A., AND ENGEL, CHR. Colorimetric determination of tcoopherol (vitamin E). *Rec. trav. chim.*, 57, 1351-1355 (1938).
6. EVANS, H. M., AND BURR, G. O. Development of paralysis in the suckling young of mothers deprived of vitamin E. *J. Biol. Chem.*, 76, 273-297 (1928).
7. FOSTER, F. L., DEWEY II, D. R., AND GALE, A. J. Van de Graaff accelerators for sterilization use. *Nucleonics*, 10, No. 10, 14-17 (1953).
8. GOETTSCH, MARRIANNE, AND RITZMANN, JOHANA. The preventive effect of wheat germ oils and of α tocopherol in nutritional muscular dystrophy of young rats. *J. Nutr.*, 17, 371-381 (1939).
9. HANNAN, R. S., AND BOAG, J. W. Effects of electronic irradiation of fats. *Nature*, 169, 152-153 (1952).
10. HUBER, WOLFGANG. Electronic preservation of food. *Electronics*, 21, No. 3, 74-79 (1948).
11. JONES, J. H., AND FOSTER, CLAIRE. A salt mixture for use with basal diets either low or high in phosphorus. *J. Nutr.*, 24, 245-256 (1942).
12. KNOWLTON, J. A., MAHN, G. R., AND RANFTL, J. W. Radiation sterilization III, The resonant transformer: a source of high-energy electrons. *Nucleonics*, 11, No. 11, 64-66 (1953).
13. LAWTON, E. J., AND BALWIT, J. S. Ionization Chambers for Measuring Cathode-Ray Dose Rate. (Unpublished Report N. RL-618, General Electric Research Laboratory, Nov., 1951).
14. LEA, D. E. *Actions of Radiations on Living Cells.* 1947, Macmillan and Co., New York, pages 8, 16.
15. MASON, K. F. Experimental muscular dystrophy. *Proceedings of the First and Second Medical Conference of the Muscular Dystrophy Association of America, Inc.*, pages 25-31 (1951-52).
16. MEAD, J. F. The irradiation-induced autoxidation of linoleic acid. *Science*, 115, 470-472 (1952).
17. POLISTER, B. H., AND MEAD, J. F. Effect of certain vitamins and antioxidants on irradiation-induced autoxidation of methyl linoleate. *J. Agr. Food Chem.*, 2, 199-202 (1954).
18. PROCTOR, B. E., AND GOLDBLITH, S. A. Food processing with ionizing radiations. *Food Technol.*, 5, 376-380 (1951).
19. PROCTOR, B. E., AND GOLDBLITH, S. A. Electromagnetic radiation fundamentals and their applications in food technology. *Advances in Food Research*, 3, 119-196 (1951).
20. ROSE, C. S., AND GYORGY, P. Hemolysis with alloxan and alloxan-like compounds, and the protective action of tocopherol. *Blood*, 5, 1062-1074 (1950).
21. SIRI, W. E. *Isotopic Tracers and Nuclear Radiations with Applications to Biology and Medicine.* 1949, McGraw-Hill Book Co., pp. 410, 413.